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PAPERS AND PROCEEDINGS OF THE 1951 ANNUAL MEETING — Part II

BIOLOGICAL EFFECTS OF DDT APPLICATIONS ON TIDAL SALT MARSHES

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Consequent to the increased use of DDT and other insecticides for the control of salt-marsh mosquitoes, there has been a growing concern over possible hazards to fish and wildlife. In an effort to evaluate properly any harmful features of such programs, and to seek means for minimizing any dangers to beneficial life, the Fish and Wildlife Service, in cooperation with other agencies, initiated an investigation in 1949. This report summarizes the results obtained during the first two years (1949–1950) of such a study.

Concerning salt-marsh mosquito control with DDT, little is known of the direct or indirect damage to fish, marsh birds and waterfowl, and to such commercially important invertebrates as blue crabs, clams, oysters, and bait shrimp. The present study has aimed to determine the extent of damage sustained by wildlife with sprayings comparable to those applied for control of mosquito larvae. However, due to the small amount of population work on many of the organisms encountered, a considerable portion of the investigation necessarily was directed toward the development of suitable study methods.

THE AREA AND METHODS

Studies were conducted on the salt marshes of Brigantine National Wildlife Refuge, Oceanville, New Jersey. In addition to the Fish and Wildlife Service, several federal and state agencies participated. The Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture furnished insecticide and the plane; the New Jersey Agricultural Experiment Station studied effects of the aerial applications upon insect pests of the area and personnel of the New Jersey Fish and Game Division assisted materially in several phases of the project.

In 1949, four study areas were established and treated by plane at rates of 1.6, 0.8, 0.4 and 0.2 pounds of DDT per acre respectively. Two applications were made, the first between August 17 and 19 mostly at high tide and the second on September 15 and 16 at low tide. Each plot included 100 acres except for the 1.6 area which was 50 acres. Realignment of the plot boundaries before the second treatment resulted in some portions of each of the areas being treated only once and other parts twice. For comparison, studies were also made throughout the summer on the fluctuations of animal populations in suitable unsprayed check areas.

Since the 1949 studies clearly established the consequences to aquatic life of the 1.6 pounds per acre application, this dosage was omitted from the 1950 program. However, in this second year of study the former 0.8 pound per acre plot received an application of 1.0 pound per acre, and the 0.4 and 0.2 areas of 1949 were treated in 1950 at rates of 0.5 and 0.25 pound per acre respectively.[1] Three sprayings were made on each area at low tide on July 6, August 4 and September 3. Although the 1.6 area of 1949 was not re-treated in 1950, follow-up studies were conducted to determine the presence of any continued effects.

[1] Hereafter these areas or dosages are referred to as the 1.6, 1.0, 0.8, 0.5, 0.4, 0.25, and 0.2 areas or dosages.

During the first year the spray used was Shell ACX-331 containing 10.75 per cent DDT in light fuel oil with an auxiliary solvent. Different dosages were obtained by varying the volume of spray applied. With this procedure, higher dosage plots received more oil solvent than the lower dosage areas. Since oil is toxic to certain forms of life, greater or lesser kills might be expected according to the amount applied. This fact recommended a change in the 1950 program, and during the second year, 20, 10 and 5 per cent oil sprays were made up for the 1.0, 0.5 and 0.25 areas respectively. Consequently, equal quantities of spray per acre were applied on each of the areas, the amount of DDT being the only variable.

Pre- and post-spray studies of populations and of animal behavior in sprayed and untreated areas were the chief investigative methods employed, and techniques used are described at appropriate places in the text. Since the majority of invertebrates are more readily affected by DDT than vertebrates, it was felt that spraying effects on the latter would be largely indirect and evidenced primarily through disturbances to invertebrate populations. Consequently, invertebrates received major emphasis in this study. Many of these serve directly or indirectly as a source of food for vertebrates, and a few, such as the blue crab, are of commercial value.

OBSERVATIONS ON BIRDS

Gulls.—Greatly increased numbers of gulls, mostly laughing gulls, *Larus atricilla,* were usually seen at low tide on the day following spraying. These increases were noted in areas where considerable mortality to fish, crabs and shrimp had occurred. The actions and cries of feeding gulls undoubtedly attracted birds from considerable distances as up to 500 were sometimes seen in an area. These concentrations largely disappeared by the second day following treatment. Thereafter, in some cases, a below-average number of gulls were present in the sprayed areas. Strip counts on the 1.6 and 0.8 plots before and after spraying in August showed an 85 per cent decrease in number of gulls following treatment. No harmful effects to these birds could be discerned, even though they consumed large quantities of DDT-contaminated animals. Usual numbers were again seen in the areas within several weeks following spraying.

Clapper Rail.—Though it was difficult to observe feeding habits of clapper rails, *Rallus longirostris,* it was evident that they consumed many DDT-affected fiddler crabs. This was indicated by the increased number of large claws of the male crabs following spraying. These are commonly discarded by rails when eating fiddlers. Surveys of the plots after treatment revealed no dead birds in 1949, but in 1950 a young rail about one week old was found dying in the 0.25 area, 40 hours after the August 4 spraying. Upon death, tissues from this specimen were analyzed and found to contain DDT in quantities sufficient to suggest acute poisoning. Since this bird was recovered on the lowest dosage plot, it seems reasonable to assume that other deaths may have occurred on areas of heavy dosage.

Following the July, 1950 application, observations were made on a total of 11 nests located in treated plots, five of which were in the 1.0 area. All nests produced successful hatches indicating no apparent effects to parents or young. Several rails collected at various times after treatment had well-filled gizzards, indicating that there was no shortage of food.

Herons.—Increased numbers of herons and egrets entered some of the study plots for a few days after spraying. None were observed eating dead fish, nor were there any indications of mortality to these birds.

Swallows.—Tree swallows, *Iridoprocne bicolor,* while very common before the August, 1949 spraying in the 1.6 and 0.8 areas, decreased greatly thereafter. Strip counts showed declines in these areas of 52 and 41 per cent respectively. Meanwhile, increased numbers of birds were observed feeding in nearby untreated areas. However, this was only a temporar change as the usual numbers were agai seen over the sprayed plot before the ne

treatment. Swallows were less numerous before spraying in the lower dosage areas and any changes thereafter were not noted.

Song Birds.—The effects of DDT on small resident song birds including the long-billed marsh wren, *Telmatodytes palustris,* sharp-tailed sparrow, *Ammospiza caudacuta,* and seaside sparrow, *A. maritima,* were determined by strip counts in the higher dosage areas. An average of 26 birds in the 1.6 area, and 29 birds in the 0.8 area were present before spraying. Afterwards averages of 26 and 32 birds respectively were seen, indicating no significant changes. No observable harm resulted to several nestlings and young birds just out of the nest in the high dosage areas. Collection and examination of both young and adult specimens five days after spraying showed that all had well-filled gizzards.

EFFECTS ON FISHES

Investigations were made of DDT effect upon the common fishes of the salt marsh, principally killifish. Two species were especially typical: *Fundulus heteroclitus,* found abundantly in all aquatic habitats, and *Cyprinodon variegatus,* which occurred largely in ponds.

General observations indicated that killifish were readily affected by DDT spray, the results being largely in accord with the dosages applied. At rates of 0.8 pound per acre and above, poisoning symptoms were observed within four hours after low-tide treatments, and at lower dosages within nine hours after spraying. The maximum number of dead and affected fish were usually seen 18 to 24 hours following spray application. In the low dosage areas, all visible effects of spraying had disappeared by the second to fourth day after treatment while in the 1.6 and 0.8 areas dead fish were seen until the fourth or fifth day.

Heavy losses of fish occurred as a result of the 1.6 dosage spraying. Small *Fundulus* less than 1½ inches long made up the majority of the kill in the creeks and ditches but there were a number of larger individuals up to 3 inches in length. Mortality was not complete and many fish were seen during succeeding tides. In ponds the kill was greater, being nearly complete in the shallow bodies. This difference was probably associated with the greater concentration of spray in the shallow water areas and the greater possibility of contact by fish.

Lower mortalities occurred in the 0.8 area and the number of dead and affected fish was only about half of that present in the 1.6 area. Even less mortality occurred in the 1.0 area in 1950 and here the losses were only a little greater than those observed in low-dosage areas. Although a number of small fish were affected within four to five hours following the 1.0 spraying, most of them recovered. The difference between the two years' spraying appears to be due to the greater volume of oil used in the 1949 operations. The effects of spraying at the lower dosages were much reduced and were confined to the smaller sized fish in the shallow ponds and ditches. A number of affected fish were noted in the areas but only a few succumbed. No mortality or evident harm to fish was observed in the check areas before or after sprayings.

Observations of effects of the various sprayings were confirmed, in a general way, by cage experiments although results from the latter were clouded by mortalities from handling and by probable weakening of fish through confinement. However, handling mortality was largely eliminated during the second and third treatments in 1950.

These experiments showed about a 70 per cent loss of fish in both creek and pond cages at the 1.0 pound per acre application. In the 0.5 and 0.25 areas, small fish (under 2 inches in length) suffered about 50 per cent reductions in both creek and pond habitats. Losses to larger fish (over 2 inches in length) in the lower dosage areas were somewhat less. Creeks showed a 40 per cent mortality in the 0.5 area and half of that in the 0.25 area. In ponds, the greatest losses to large fish occurred in the 0.25 area where a 45 per cent mortality was observed as compared to a 20 per cent

loss in the 0.5 area. *Cyprinodon* killifish proved to be more resistant to DDT spray than *Fundulus* in the pond tests.

Cage studies were also made to determine if fish in the main drainage creeks outside each of the treated areas were affected by DDT spraying. No mortalities occurred among large or small fish placed at an average distance of about 1800 feet beyond the far ends of the plots.

A more natural means of confinement used in the 0.4 and 0.2 areas consisted in screening-off sections of creeks which retained considerable water at low tide. Dead and live fish subsequently recovered indicated a mortality of 86 per cent in the 0.4 area following spraying. However, almost no mortality was observed in a similar experiment in the 0.2 area.

STUDIES ON INVERTEBRATES

Insects.—Net sweepings along established courses, before and after DDT sprayings, gave indices of the populations of various kinds of insects in the marsh and also denoted the comparative decline in numbers following treatments. Of the insects present on the salt marsh, leafhoppers (Homoptera) and flies (Diptera) were found to be most abundant in numbers of individuals.

Severe reductions in populations resulted from DDT spraying. Declines following a single spraying ranged from about 15 to over 80 per cent, the losses being roughly proportional to the dosage applied. True bugs (Hemiptera) were almost completely eliminated. Leafhoppers and flies were more resistant, especially the former. Survival of various species proved to be distinctly greater in tall grass than in short grass, probably due to the greater screening effect of the higher vegetation.

The duration of spraying effects on insects was found to depend upon the dosage applied and the time of the year. Areas treated with high dosages (0.8 and above) in mid-August showed continuing declines in populations through September followed by complete recovery the next summer. However, the residual effects from treatments in early July disappeared largely in less than a month although populations had still not attained pre-spray levels by the end of the summer. On the other hand, sprayings at lower dosages (0.5 and below) were followed by complete population recovery within seven weeks.

Repeated treatments strongly curbed increases in insect numbers. Populations in the 0.5 and 0.25 areas were reduced about 90 per cent by the end of the summer as compared to pre-spray populations while during the same period the check area populations rose approximately 80 per cent.

Blue crabs (Callinectes sapidus).—These animals proved to be very susceptible to DDT applications and in some cases suffered severe losses. In the watercourses, these reductions as well as other effects of DDT spraying were demonstrated by means of general observations, by trapping crabs in commercial type crab pots and by periodic confinement and counting of crabs in screened sections of creeks and ditches.

Screened channel sections were used to help appraise crab mortality in conjunction with the second 1949 spraying and all the 1950 treatments. Screen barriers extending above the high tide level were erected within the channels of creeks and ditches of each area and enclosed portions of individual creeks or of creek systems ranging up to 4300 feet in length. The screens were adjustable and could be raised and lowered to permit the passage of crabs or to enable confining them at low tide for counting purposes. All enclosed creek channels contained sufficient water at low tide to maintain crabs. Dead individuals were removed as they were found.

Information on spraying effects on blue crabs was also obtained by means of crab-pot catches taken at weekly intervals throughout the 1950 season. Resulting data, although not as accurate as those obtained from the enclosed creek systems, tend to confirm the findings obtained by other methods.

General observations together with screened-channel studies and crab-pot

catches showed that the greatest losses among crabs occurred at the higher rates of application (0.8 pound per acre and above). Low-tide sprayings with these dosages produced typical symptoms of DDT poisoning within two hours after treatment. However, the greatest effect from spraying at these and at lower dosages did not occur until 18–24 hours later. Surveys at this time in creeks and ditches of the 1.6 area revealed a very heavy mortality of crabs that had been present at the time of spraying. The few live crabs that were seen showed effects of DDT poisoning. Probably some affected crabs had left during preceding ebb tides but the numbers of dead crabs that were found indicated that the kill within the area had been nearly complete. Results in the 1.0 and 0.8 areas were similar although mortality was not as sudden and about one-third of the crabs present 24 hours after spraying were still alive. Crabs entering these areas during subsequent incoming tides suffered mortalities for a period of about two weeks.

Repopulation was slow and was approximately half completed in four weeks. Complete recovery in the 1.6 area treated in both August and September did not occur until the middle of the succeeding summer. The 0.8 plot of 1949 received a single 1.0 pound treatment again in July, 1950 and at the end of this second season its average population was approximately one-fifth as great as the population prior to treatment the previous year. Seven weeks were required for the population to rebuild to the 1950 pre-spray level.

Effects of treatments at the lower dosages were more variable. General observations during the first season indicated light mortality in the 0.2 area and only a moderate kill in the 0.4 area. However, confinement of crab populations in the creek channels of these areas revealed kills of 60 per cent in the 0.2 and 90 per cent in the 0.4 area during periods of one and two weeks respectively.

Channel enclosures operative during the period of a single tide showed losses of over 80 per cent in the 0.5 area and from 20 to over 40 per cent in the 0.25 area. DDT mortality in both areas was of about seven days' duration. The number of dead crabs recovered in the 0.5 area following spraying did not account for the total number missing and indicates that either crabs were dying outside the creek system or that they did not enter in the usual numbers. Within a day or so after the termination of mortality, crabs were as plentiful in the 0.25 area as before spraying. In the 0.5 area this process required two additional weeks.

Pond habitats showed greater losses than creeks and ditches. Nearly complete mortality was observed following single treatments of ponds at the high dosage rates. After the third spraying a survey of 19 ponds in the 0.5 area revealed no living crabs while at the same time only two could be found in 16 ponds in the 0.25 area. As in the case of fish, more severe kills in these low dosage areas were noted in shallow ponds than in deep ponds. The lack of flushing action, except by spring tides, undoubtedly accounted for the greater kills observed in ponds as compared to creeks and ditches. Tides, of course, also regulate the time and frequency with which crabs from outlying areas can enter and restock these depleted ponds.

Investigations during the 1950 season on an unsprayed plot indicated that the crab population of that area increased until the latter part of July after which a fairly stable level was maintained until the middle of September. A low and uniform natural mortality occurred throughout the season. This natural mortality rate gave a basis for comparison with losses on the sprayed areas.

Fiddler Crabs.—The evaluation of DDT mortality to salt-marsh fiddler crabs, *Uca pugnax,* proved difficult due to their burrowing habits. Losses occurred and in some cases were very great. In general, however, they were proportionately less than those suffered by blue crabs.

Besides general observations, a number of techniques were employed to measure fiddler crab populations and mortality.

The use of square frames of screen or metal, measuring 1 to 2 feet on a side and 18 inches high, proved of most value. These were placed in previously dug holes in banks from which all crabs had been removed. They extended at least 12 inches below the surface, the greatest depth at which fiddler burrows were encountered. After the mud was replaced, a known number of crabs were introduced and a cover of hardware cloth or screening placed on top to prevent escape of fiddlers and depredation by birds. Counts of live and dead crabs dug after spraying indicated mortalities in the different dosage areas.

Another procedure involved the use of a foot-square frame having sides 6 inches high. After this frame was forced a short distance into the ground in selected localities, collections and counts were made of all the small crabs and other invertebrates within its confines. Sampling by this means indicated considerably less mortality to small fiddlers in grassy, more protected areas than in open banks.

Kills in areas treated at dosages of 0.8 pound per acre and above were more immediate than in those treated at lower rates. Many dead and dying crabs were noted in the former areas on the day following spraying, but peak mortalities were noted on the second day. Thereafter, deaths declined and mortality largely ceased 10 days after spraying. The casualties in bare flats were proportionately greater than those occurring on creek and ditch banks where the drainage was better.

In the lower dosage plots, losses were usually first noted on the second day after treatment and were greatest on this or the third day. By the fifth to seventh day after spraying no further mortality from DDT could be observed.

Counts of crabs dug out a week after spraying indicated a total reduction of 42 per cent in the 0.5 area and 24 per cent in the 0.25 area of which 22 and 11 per cent respectively were due to known mortality. At the same time the check area suffered an eight per cent reduction and one per cent known mortality. Although this method was not used in the higher dosage areas, a similar technique there revealed mortalities up to 50 per cent.

The studies also indicated that losses among small-sized fiddlers less than 0.5 inch wide were greater than those among larger individuals. Mortalities ranged 10–15 per cent higher in the 0.25 area and were complete or nearly complete in the 1.6 plot.

Many affected, sluggish crabs were seen after sprayings. Some of these probably survived but many were eaten by birds as evidenced by the greatly increased numbers of large claws of the males. Comparisons were made of the average numbers of claws found per day along the banks of the enclosed creek and ditch systems in each area. These indicated that mortality from spraying was from 3.5 to 34 times as great as that found either before treatment or after DDT mortality had ceased. The greatest increase (34 times) was observed at the higher dosages.

Some dead crabs were noted also at distances of over 200 yards beyond the boundaries of the sprayed plots. Such observations indicate that as a result of spray drift and the transport of DDT by tidal creeks and ditches, the hazards of treatment are not confined to the limits of the sprayed plots.

Other Invertebrates.—Soil-surface sampling indicated no observable effects to mussels (*Volsella demissa*) from DDT applications. A slight seasonal increase in numbers was noted in these studies. Groups of mussels were also located and counted at intervals throughout the summer. No mortality was observed after the August, 1950 spraying. Some deaths occurred in September but the same was also noted in the check area.

Saltmarsh snails (*Melampus lineatus*) were very common and likewise did not appear to be affected by DDT treatments. Soil-surface sampling showed a general increase in the total numbers and in the total volume of snails in all plots following spraying. In similar manner, the average snail size increased through the

summer in all except the 1.6 plot where increased numbers of small individuals reduced the size average slightly. Although counts in the 1.6 area in 1950 were somewhat below the numbers recorded the previous year, a similar situation prevailed in the check area.

A number of dead and sluggish clam worms (*Nereis* sp.) were noted on the soft mud bottoms of shallow ponds and drained creeks within a day following spraying. Although such effects were observed in all the study plots, they were most noticeable in the high-dosage areas. Mortality appeared to extend for several days. No quantitative counts were made.

Bait shrimp (*Palaemonetes pugio*) proved very susceptible to DDT poisoning. Considerable numbers of dead individuals were noted along creek and ditch banks within 12 hours after spraying. These observations were confirmed by effects on shrimp confined in cages as well as by seine hauls made under standard conditions. Mortalities were severe in the 0.5 area and light to heavy in the 0.25 area. However, some live shrimp were always seen after spraying suggesting either that not all were affected or that enough DDT had been washed out to make these waters tolerable. Mortality apparently ceased by the third day following application and more live shrimp were seen thereafter. Two weeks after spraying, they were as plentiful as before treatment. Undoubtedly reinvasion accounted in large part for this repopulation.

Soil-surface sampling revealed clear-cut evidence of the high susceptibility of marsh fleas (*Orchestia grillus*) to DDT spray. Following the August, 1949 treatment, no live individuals were seen in any of the areas. Second-year observations in the 1.6 plot showed that these amphipods were still absent one full year following spraying. Consequently, in addition to being highly susceptible, it appears that this form is slow to reestablish itself on treated areas. Live marsh fleas were noted after the August, 1950 treatment in a high part of the 0.25 area under a dense mat of dead grass. This indicates that they can survive if, in addition to protective cover, they are above the normal tide level of DDT-bearing waters. During the two-year period, populations in the check area maintained themselves or increased.

Salt-marsh sowbugs (*Philoscia* sp.) showed DDT susceptibility similar to that of marsh fleas. However, several live individuals noted in soil samples after spraying suggest that they may be more resistant.

Contrary to reports of high resistance by some spiders to DDT, the present investigations indicate these salt-marsh arachnids suffered heavy losses. Within 24 hours of spraying, dead and dying individuals of the commonly distributed wolf spider were noted throughout the treated areas. However, conspicuous numbers of dead spiders were apparent for only two days after spraying.

Results of soil sampling indicated 50 to 90 per cent reductions in the numbers of ground-inhabiting spiders after spraying. The casualties were greatest in areas of heaviest application. Meanwhile check-area populations remained the same. There was no recovery of spiders in sprayed plots by the end of the first summer but studies in August, 1950, in the 1.6 plot (not treated second year) showed that populations were only a little below the original pre-spray levels.

The effects upon web-building spiders were much the same. Webs inhabited by spiders before spraying were deserted afterwards although similar studies in check areas revealed practically no reduction in number of active webs. Populations sprayed in midsummer did not show any degree of recovery in net-sweeping counts until early the following summer but the effects from treatments in early summer persisted for less than a month.

In contrast to the decline of spiders, there were general increases in red mite populations following spraying. This was revealed by soil samples and by net sweepings. The largest gains were observed in the 1.6 area. Meanwhile check area populations remained nearly stable. Similar large increases of red mites following DDT spraying have been noted elsewhere.

SUMMARY

Experimental studies were conducted on a New Jersey salt marsh during the summers of 1949 and 1950 to determine the hazards to wildlife from mosquito control involving use of DDT. Four plots were established and treated by plane at dosages ranging from 0.2 to 1.6 pounds of DDT per acre. Each plot was sprayed two or three times each year at approximately monthly intervals, except the 1.6 area, treated only in 1949. Studies were conducted before and after each treatment to determine the effects of spraying upon populations of the principal wildlife species and upon invertebrates which serve as food for wildlife.

Birds apparently suffered little direct harm although a one-week old clapper rail died from acute DDT poisoning on the 0.25 area. Local movements of swallows and gulls were noted in response to depletion or increased availability of food but these were only temporary and no mortality was evident. No changes resulting from sprayings were observed in numbers of song birds after the breeding season and they, along with rails, appeared to find sufficient food.

Killifish proved susceptible to DDT spray with heavy kills occurring at the 1.6 and 0.8 pounds per acre applications. Visible effects of spraying continued up to five days after treatment. Only light kills were observed at dosages below 0.5 pound per acre. However, cage experiments at these same levels indicated considerably higher mortalities to confined fish. Ponds generally sustained greater losses than did creeks and ditches. Repopulation of waterways by fish from outside the areas occurred rapidly except in the case of ponds not affected by daily tide flows.

DDT applications were very toxic to blue crabs. Dosages of 0.8 pound per acre and above resulted in complete or nearly complete kills of the crabs. Such areas remained toxic for two weeks. Lower dosage levels showed population reductions ranging from 20 to 80 per cent over a seven-day period following spraying. Time required for repopulation varied from a few days (0.25 area) to 2 weeks (0.5 area) after mortality ceased. As with fish, crab losses in ponds were higher than those in creeks and ditches.

In common with other crustaceans, fiddler crabs were readily affected by DDT treatments. Losses of 10 to 20 per cent occurred in the 0.25 area and 20 to 40 per cent in the 0.5 area. Somewhat greater mortality resulted at higher dosages. Small fiddlers less than 0.5 inch wide were most susceptible.

Other small invertebrates were variously affected. Amphipods, sowbugs and bait shrimp incurred very heavy losses while insects, spiders and worms were somewhat more resistant. Little or no apparent harm resulted to red mites, snails and mussels.

STORING ADULT MOSQUITOES

Because mold was destroying so many adult specimens of mosquitoes during a recent stay in India, the following methods for storing were developed: 1. Flat wooden storage boxes were built by local carpenters. 2. Beeswax, to serve as a substitute for cork, was purchased in the bazaar. 3. The following mixture was melted and poured into the bottom of the box, and allowed to cool, ⅔ (by volume) beeswax, ⅓ naphthalene flakes. 4. Any cracks which formed in the cooling process were pressed out. 5. After white paper was glued on the bottom, the box was ready for use.

For the storage of unpinned mosquitoes, metal ointment boxes were used as follows: 1. One quarter inch of flakes was placed on the bottom. 2. The flakes were melted by holding the box over an alcohol lamp and allowed to cool. 3. A small amount of cotton was pressed down over the naphthalene. 4. The heating process was repeated allowing the naphthalene to vaporize through the cotton. Occasionally it was necessary to press down the cotton afterward but only after it was thoroughly cooled.—CHARLES O. MASTERS.

CONTROL OF ADULT MOSQUITOES AND BLACK FLIES BY DDT SPRAYS APPLIED FROM AIRCRAFT [1]

A. W. A. BROWN,[2] R. P. THOMPSON,[3] C. R. TWINN,[4] AND L. K. CUTKOMP [5]

It has already been demonstrated in various parts of subarctic Canada that the aerial spraying of mosquito breeding areas with DDT at 0.25 pound per acre kills, on the average, approximately 90 per cent of the *Aedes* larvae present (Twinn, Brown, and Hurtig, 1950). However, the effect of such treatment of areas of 5 and 17 sq. mi. was to reduce the adult mosquito population throughout the remainder of the season only to approximately one-half of that in unsprayed areas. A large-scale experiment was performed at Goose Bay, Labrador, in 1950, to ascertain the effect of a single aerial spraying applied to kill adult mosquitoes shortly before they attained their maximum numbers. The effect of this spraying on adult black flies was also observed.

THE LOCALE AND THE MOSQUITO SPECIES

At Goose Bay, Labrador (lat. 60° S, long. 53° N), the air base is occupied by both Canadian and American personnel. It is situated on a sandy plateau covered with lichens and scattered, small black spruce. Eastward and southward it drops 100 ft. to a plain bordering Terrington Basin and the Hamilton River, and bearing a relatively dense forest of spruce with admixed birch, willow, and alder. This area was included with the plateau in the sprayed area. East and north of the sprayed area are extensive sphagnum bogs, and to the west the ground rises in rocky hills clothed with spruce. Few mosquitoes breed on the sandy plateau, but the bogs and numerous forest pools in the surrounding low-lying areas are a major source of infestation.

The predominant species were *Aedes punctor* (Kby.), *A. implacabilis* (Wlk.), *A. communis* (DeG.), and *A. pionips* Dyar. These black-legged forest species cannot readily be distinguished from one another in the female form, but they were abundant in the larval stage, and probably comprised the great majority of the mosquitoes attacking man. Other species, in smaller numbers, included *A. fitchii* (F. and Y.), *A. canadensis* (Theo.), *A. cinereus* Meig., and *A. diantaeus* H., D., and K. Overwintering females of *Culiseta impatiens* (Wlk.), *C. alaskaensis* (Ludl.), and *Anopheles earlei* Vargas, although present in moderate numbers earlier, were scarce or absent by the time the spray was applied.

THE AERIAL SPRAY AND ITS APPLICATION

With the aid of available maps, an area of 19 sq. mi. around the air base was delimited, and marker points for the aircraft tracks were placed at 200-yd. intervals along roads selected as base lines. The area was divided into eight large sections, each measuring slightly more than two square miles, and two smaller, intercalated sections (Fig. 1).

Two spraying flights were made each night, and each flight covered two square miles. The line of flight for each track of spray was indicated by a luminescent marker that served as the starting point, and by the magnetic heading on which

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the pilot of the aircraft was instructed to fly; the length of the track determined the number of seconds of flight that the spray valve was to be open. As the speed of the aircraft was 140 m.p.h., a swath one mile long was covered in 25.8 sec. The height at which the aircraft was to fly was governed by the speed of the crosswind component of the wind prevailing at the time. The height-wind products (Twinn, Brown, and Hurtig, 1950) selected were, on the average, between 1,000 and 1,500 ft.-mi./hr. The wind speeds were obtained by radio from the control tower of the airfield, and heights were relayed to the aircraft from the ground by wireless. All operations were performed under conditions of zero temperature gradient; this was checked at a mobile meteorological station consisting of two shield thermo-couples attached to a staff at heights of one metre and two metres, and connected with a galvanometer (Fig. 3). Spraying was commenced between 1900 and 1950 hr., and finished between 2050 and 2200 hr.

The aircraft employed was an R.C.A.F. Dakota Mark I (C-47) used for search and rescue duties on the station. It was fitted with a temporary installation consisting of two auxiliary fuel tanks designed for the Mitchell (B-25) aircraft. This could be installed by four men in three and a half hours. The spray solution was led to a vertical emission pipe by means of 4-in.

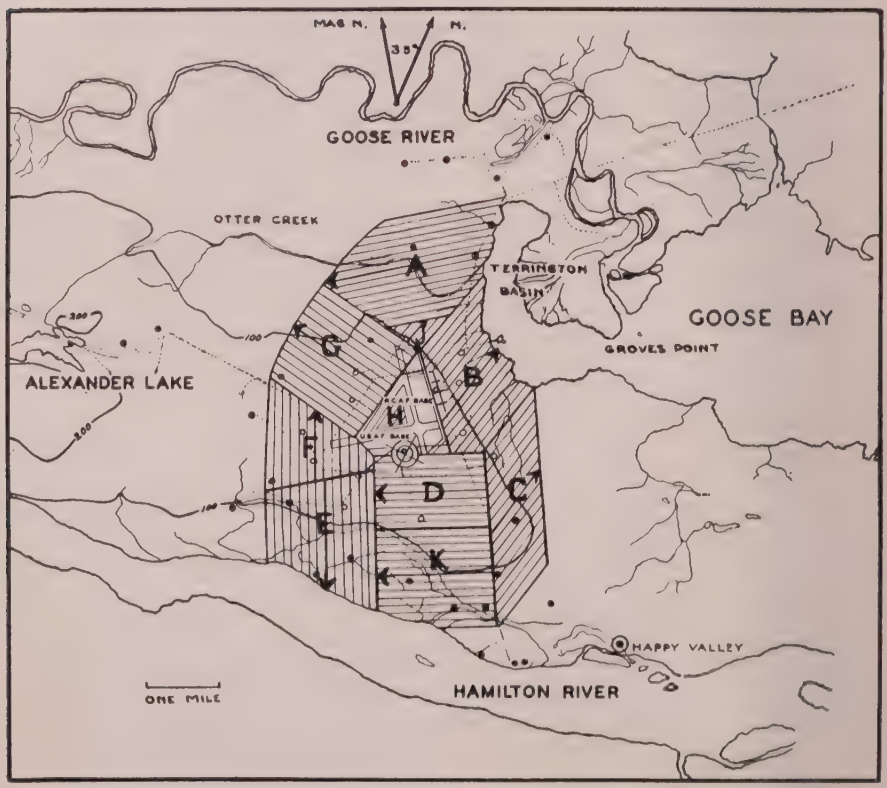

FIG. 1. Map of Goose Bay showing location of 10 plots sprayed with DDT. Fine lines indicate lines of flight of aircraft; arrows, the direction of flight; black dots, the locations of biological assessment points inside and outside the sprayed area.

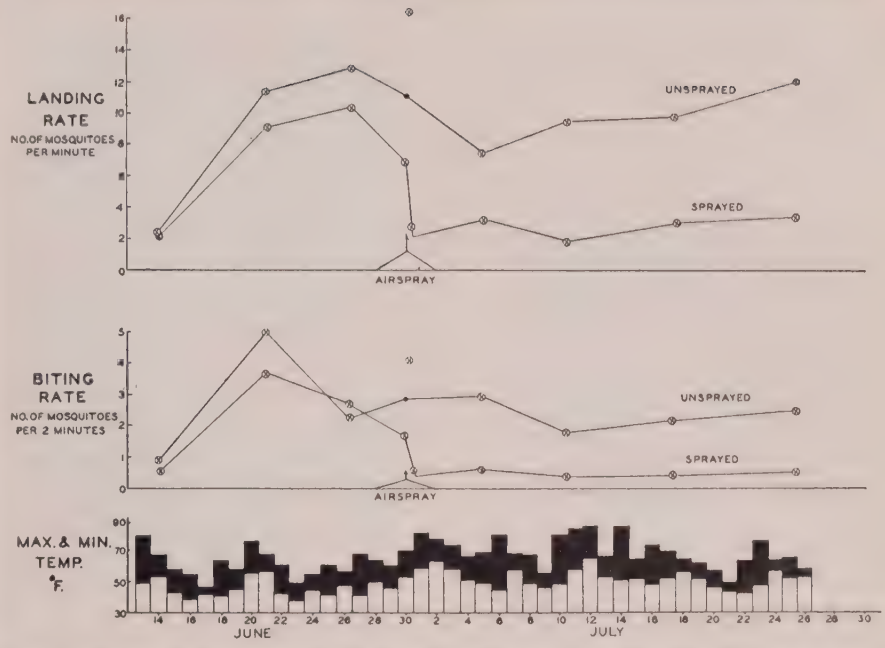

FIG. 2. Landing rates and biting rates of mosquitoes in sprayed and unsprayed areas, and daily maximum and minimum temperatures, June 13–July 26, 1950, Goose Bay, Labrador. The landing and biting rates obtained for the unsprayed areas during the airspray operation, and plotted above as the figures for June 30 were unusually high, as they were taken at dusk, whereas all other assessments were made during the day; therefore the lines are drawn through a point representing two-thirds of their numerical value.

aluminum ducts attached to the sumps of the tanks (Fig. 4). A full load of spray contained 600 imperial gallons.

A quick-acting gate valve of special design led to an emission pipe extending vertically downwards through the floor and the fuselage skin. To the skin was affixed an emission device provided with an air scoop (Fig. 5). This consisted of a vertical section 2.5 in. in diameter and 18 in. long, tapered to 2 in. in diameter and affixed to a 2-in. elbow that directed its aperature rearwards; on the end of this 2-in. elbow there was a 5-in. length of 2-in. pipe, perforated by 28 holes, each three-eighths of an inch in diameter, and the end tapered into a cone perforated with 4 one-quarter-inch holes. This pipe was enclosed in an air scoop, with the forward opening 6 in. in diameter and tapered over a length of 7 in. to a throat 4 in. in diameter; this throat was 5 in. long, and completely enclosed the perforated section of the pipe, then widened over a 3-in. length to a rearward opening 6 in. in diameter. The cross-sectional area of the annulus around the perforated section through which the spray was emitted was one-third of the cross-sectional area of the entrance to the air scoop.

The emission rate of the spray solution through this device, by gravity feed alone, was 1.1 gal. per second. The arithmetic mean of the diameters of the droplets of oil spray from this device was 97 microns, and the mass median diameter was 400 microns. These figures were obtained from an assessment at 40 sampling points

FIG. 3. Temperature gradient apparatus at field meteorological stations. FIG. 4. Spray installation in the fuselage of a Dakota aircraft. FIG. 5. Straight emission pipe and air-scoop modification. FIG. 6. Air-scoop device in place on underside of fuselage of aircraft.

at 10-yd. intervals downwind of the emission track of the aircraft, which was flown at a height of 200 ft. in a 5-m.p.h. crosswind. At each point was placed a 4-in. petri dish containing a microscope slide (18.8 sq. cm.) coated with an oleophobic silicone (General Electric Drifilm 9987). The droplets of the spray, dyed with du-Pont oil red, were sized under a binocular microscope, with the Porton modification of the Pattison-Cawood graticule. The spread factor, or lens-droplet ratio, was determined by calibration with a small syringe to be 2.38. The droplet spectrum so obtained is shown in Table 1. The finer droplets in this spectrum were also sampled by means of impactors (Casella's model of K. R. May's design), fitted with silicone-coated slides and with an air intake of 10 litres per minute. Between 10 and 50 droplets, ranging between 5 and 30 microns in diameter, were obtained on the first slide, and no finer droplets were obtained on the succeeding three slides.

At the same time the droplet spectrum of the 2.5-inch straight emission pipe, used in the 1949 operations, was assessed. The figures in Table 2 show an arithmetic mean diameter of 79 microns and a mass median diameter of 340 microns. From this it is apparent that the air-scoop modification did not improve the performance of the straight emission pipe.

The spray solution consisted of a commercial DDT concentrate diluted with 5.7 parts of domestic fuel oil. The concentrate consisted of 25 per cent (wt./wt.) of DDT in Velsicol AR-60 (trimethylnaphthalene) solvent; hence each 45-gal. drum, weighing 500 pounds, contained 125 pounds of DDT. For each aircraft flight two drums of the concentrate were mixed with 510 gal. of fuel oil. This gave a 4.2 per cent (wt./vol.) solution of DDT in oil. The spray operations for each flight were so adjusted that the aircraft landed with from 12 to 100 gal. of spray solution in its tanks. The emission rate, as far as could be seen, remained almost constant throughout. The emitted dosage of DDT on each of the areas ranged between 0.151 and 0.187 pound per acre. The outlying areas were treated first, and the operation terminated with the treatment of the Canadian camp itself. The average dosage emitted over the whole area was 0.165 pound per acre.

Effect of Airspray on Mosquitoes

Forty sampling points were established throughout the area served by roads (Fig. 1). Landing rates and biting rates of mosquitoes and black flies were recorded usually by three observers working together. For mosquitoes, the landing rate was the number of mosquitoes landing on the front of the trousers between the waist and the knees and sideways to the seams during the third minute of observation; the biting rate was the number of mosquitoes biting the bared forearm between the wrist and the elbow during the third and fourth minutes of observation. Four pre-spray and five post-spray assessments were made in the area. The figures obtained on the mosquitoes (based on 120 observations for each assessment of the entire area) are plotted in Fig. 2.

Emergence of *Aedes* spp. commenced on June 1, and by June 14 they had become a nuisance about the camp buildings. By the third pre-spray assessment, June 26–27, the average landing rate in the central area had risen to 10.35, and in the outlying areas to 12.90 per minute, and the biting rates were 2.61 and 2.27, respectively. Personnel were being bitten in their sleeping quarters throughout the camp. Larval development was almost completed, except on the Hamilton River flats, where some pools still contained up to two larvae per dip.

The airspray operation was commenced on June 28, and was completed on July 2.

The first post-spray assessments in the sprayed areas were made in the evenings, 24 hr. after each spray treatment, during the period June 29 to July 3. The average landing rate was 2.37 and the average biting rate 0.60. In the unsprayed, check areas the average landing and biting rates during approximately the same period (June 28–July 2) were 16.35 and 4.08. These results are plotted in Fig. 2 as the

TABLE 1. Droplet spectrum of spray from air-scoop emission device on Dakota C47. Numbers of droplets of various sizes deposited on coated slides exposed various distances downwind of emission track. Goose Bay, Labrador, 1950.

Droplet Diameter: (microns)	5	10	21	31	42	52	63	75	105	125	180	270	360	420	540	720
Yards Downwind																
50															0.9	
60															1	
70														2	1	1
80														2	1	
90												4	3	4		
100												1	8	7		
110											1	2	1	1		
120											5	30	15	7		
130										8	59	28	1			
140								1	9	3						
150							1	3	2	5	6					
160				3	12	17	12	10	14	15	10					
170			3	8	19	23	26	15	18	10	3					
180			8	5	18	17	8	5	2							
190	2	4	5	10	8	2	5	8	2							
200		3	2	7	8	12	8	9	5							
210			6	12	37	28	13	6								
220		1	7	19	17	27	10	5								
230		1	1	3	18	15	9	11	1							
240				1	7	13	17	24	17	3						
250					1	6	10	22	9	10						
260			1	1	1	2	8	15	12							
270		1	–	–	3	3	6	6	1	2						
280			1	2	3	4	4	11	9	1						
290		1	–	–	3	5	3	10	2							
300					2	3	1	6	5	4						
310								1	4	11						
320				1	2	–	1	8	1							
330						1	5	2	1							
340					4	4	1	2	3							
350		2	2	1	–	1	3	2	1							
360			3	–	1	–	–	3								
370			1	–	1	3	–	1								
380					1	1	3									
390			1	2	2											
400					1	2										
Totals	2	13	41	76	169	201	168	186	118	72	84	65	28	23	3.9	1

TABLE 2. Droplet spectrum of spray from straight emission pipe on a Dakota C47. Numbers of droplets of various sizes deposited on coated slides exposed various distances downwind of emission track. Goose Bay, Labrador, 1950.

Droplet Diameter: (microns)	5	10	21	31	42	52	63	75	105	125	180	270	360	420	540
Yards Downwind															
90													1	1	10
100								1	-	-	4	-	4	13	
110									1	3	18	49	17	8	
120									2	10	92	78	8		
130					2	3	3	2	11	24	40	19	1		
140						6	14	36	58	82	54	10			
150				2	2	8	14	24	38	60	78	10			
160			3	16	28	34	26	24	27	22	6				
170		4	10	42	65	49	5	6	2						
180		5	34	35	26	27	16	9	14	2					
190		6	14	36	40	46	40	26	18	2					
200		6	26	45	45	31	19	5	3	2	6				
210				14	16	48	10	24	20	8					
220			2	17	13	15	4	7	3	3					
230				7	10	10	8	3	2						
240		1	3	5	9	14	16	13	7	2					
250		1	7	9	4	6	5	3							
260	2	3	5	6	4										
270			1	-	2										
280		2	20	20	20	32	17	10							
290		2	24	44	52	52	16	6	2						
300		7	21	24	49	42	11	7							
310		13	20	15	12	4	2	1							
320		6	12	13	6	2	2	1	1						
330		3	11	15	6	3									
340	2	4	4	12	10	10	3								
350		5	16	11	15	5	5	7	1						
360				4	9	6	5	2							
370			1	8	7	6	6	10	3						
380			2	4	9	7	3								
390			1	2	2	9	5	7							
400		1	3	3	3	8	5	2							
Totals	4	69	308	715	466	483	260	246	213	220	298	166	31	22	10

figures for June 30, but the lines are drawn through a point constituting two-thirds of their numerical values, to put them on an equivalent basis with the daytime counts used in all other assessments.

Population assessments in both sprayed and unsprayed areas were repeated on July 4–6, July 10–11, July 17–18, and July 25–26. The figures are plotted in Fig. 2. During the period covered by these assessments (July 4–26) the average landing rates in the unsprayed area ranged from 7.27 to 12.02 and the average biting rates from 1.70 to 2.87. Comparable average figures for the sprayed area were landing rates, 1.80 to 3.27, and biting rates, 0.27 to 0.61, approximately one-fourth and one-sixth, respectively, of those in the unsprayed area.

The differences between the pre-spray and post-spray results were tested by an analysis of variance applied to the figures obtained block by block, using the F distribution method. All of the differences were significant at the 5 per cent level, and half of them were significant at the 1 per cent level. The p values obtained for the comparisons were as follows:

	Landing Rates	*Biting Rates*
Fourth pre-spray vs. first post-spray	0.025	0.005
Third pre-spray vs. first post-spray	0.016	0.006
Third pre-spray vs. fifth post-spray	0.032	0.047

The final assessments, made on July 25 and 26, four weeks after the spray was applied, showed that the infestation in the treated area had not significantly increased. The average landing and biting rates in the sprayed area at this time were 3.24 and 0.50 as compared with 12.02 and 2.46 in the unsprayed area. If the final assessments for the sprayed area are grouped on the basis of central and peripheral areas, the average landing rate at the periphery is 6.29 as compared with 0.77 at the center. Furthermore, throughout the post-spray period the average landing rates at the center did not exceed 1.27. The biting rate in the central area at the last post-spray assessment was 0.21, slightly less than the rate of 0.31 obtained by the first post-spray assessment. The average figures for the peripheral points were increased by the large mosquito population on the Hamilton River flats, which, by the end of July, was not noticeably different from that in adjacent unsprayed areas.

After the area was sprayed, mosquitoes were not seen on window screens in the camp, whereas four to eight per screen (and a maximum of 30) had been observed before the spraying. Mosquitoes first reappeared on screens on July 10, and the maximum number observed on any window screen between then and July 22 was six. Most screens remained free of them. The comparative absence of biting flies was favorably commented on by occupants of the base and by visitors.

As a result of the spray application, the outside doors of most of the buildings in the Canadian camp were left open, despite the absence of screen doors. This was encouraged by the excessive heating of the buildings, especially at nights. Mosquitoes eventually became a nuisance in the sleeping quarters on July 23 and 24, large numbers presumably being attracted by heat. They disappeared on July 25 and 26, after a period of heavy rain, when the quarters were not heated. Also, by July 23, the numbers of mosquitoes and black flies affecting children at play in the family housing area was causing some concern. As a very low biting rate is required to ensure the comfort of children at play, the camp and residential areas were again sprayed on July 28. This marked the termination of the main experiment.

Two smaller area spray experiments were performed, outside the area previously sprayed, to ascertain the effects of the treatment 1 hour and 14 hours after spraying. An area of 2.6 sq. mi. at Happy Valley, in the thick spruce forest on the Hamilton River flats, was treated at 0.15 pound of DDT per acre on July 15. The average landing rate dropped from 16.0 to 3.0 in the first hour, and to 2.2 in 14 hours; the average biting rate fell from 4.2 to 0.2 in the first hour, and increased slightly, to 0.5 in 14 hours. Hence, 14 hours after spraying, the landing rate was reduced by 86 per cent and the biting rate by 88 per cent.

A second assessment of the initial effect of the spray was made in open spruce forest near the Goose River on July 28. An area of 2.3 sq. mi. was sprayed at 0.16 pound of DDT per acre. Here the decreases in landing and biting rates were approximately 66 per cent in one hour and 98 and 87 per cent, respectively, in 14 hours.

Effect of Airspray on Black Flies

The numbers of black flies in the Goose Bay area had been substantially reduced by the treatment of infested streams with DDT larvicide in June. This treatment had been applied to all streams known or believed to be infested with black fly larvae over an area of approximately 200 sq. mi. surrounding the air base. The details and results of this treatment will be presented elsewhere. Nevertheless, the insects became sufficiently abundant to be troublesome about the air base by the end of June. Two species, *Simulium venustum* Say and *Prosimulium hirtipes* Fries, appear to be mainly responsible for attacks on man in this region. During the large-scale spray operation of June 28–July 2, which was directed mainly against mosquitoes, adult black flies were observed to be quickly killed by the spray. In spite of this, the landing rate 24 hours after treatment was greater than before; this is attributed to rapid infiltration, since the second post-spray assessment indicated that the landing rate in the surrounding unsprayed area had increased considerably, and was over twice that in the sprayed area. This differential persisted during the third and fourth post-spray assessments, but at the last assessment, on July 25–26, it had almost disappeared. The black flies were most abundant near the Goose River, north of the base, on a dry sandy plain covered with slashed and burned spruce, where mosquitoes were few; on the other hand, black flies were few in deep woods near the Hamilton River south of the base, where mosquitoes were abundant.

Observations at Happy Valley on July 15 showed black fly landing rates of 1.4 before the spray, 1.3 immediately after the spray, and 0.4 the following morning. On this basis the reduction, 14 hours after treatment, was 71 per cent.

Observations in the Goose River area on July 28 showed a complete disappearance of black flies immediately after the spray, partially because of the failing light. The landing rate the following morning showed a decrease of 50 per cent as compared with the previous morning, and the number of adults taken by sweeping with nets had decreased by 71 per cent. The figure for the decrease might have been greater if the morning before had been as warm as the morning after.

Incidentally, the only creek that had not been treated with larvicide (Stream 145, Terrington Basin) was cleared of larvae, but not of pupae, by the airspray.

Acknowledgments

The Royal Canadian Air Force provided the aircraft, air and ground crews, spray material, transport, and certain other facilities used in carrying out this project. The authors wish to acknowledge with gratitude the essential part played in the aerial operations by Flight Lieutenants S. W. Yoder, D. R. Cuthbertson, and E. de Niverville. Acknowledgment is also made of assistance in the activities on the ground given by Flight Cadets G. C. Bending, H. T. Bonney, G. H. Hunter, and R. E. Paulette, of the R.C.A.F., and by J. S. Barton, G. T. Crosson, and J. J. Tibbles, of the Division of Entomology, Ottawa.

Summary

To control adult mosquitoes an area of 18.7 sq. mi. at Goose Bay, Labrador, was sprayed between June 28 and July 2 with a 4.2 per cent DDT-fuel oil solution at an average dosage of 0.165 pound of DDT per acre by means of a Dakota C-47 aircraft fitted with a gravity-feed emission pipe modified with an air-scoop. Assessment of the sizes and distribution of the spray droplets showed that the air-scoop did not improve the performance of the straight emission pipe installation.

The initial effect of the spray on mosquitoes, mainly *Aedes* spp., was to reduce the landing rate by 86 per cent in dense forest and by 98 per cent in open forest. The long-term effect was to reduce the average landing rate from 9–10 to 2–3 per minute; four weeks after spraying the average landing rate in the sprayed area was 3.2 per minute as compared with 12 per minute in the unsprayed area. Average biting rates in the sprayed and unsprayed areas showed similar results.

The initial effect on black flies was to reduce their landing rate by approximately 70 per cent, although results were highly variable. The landing rate in the sprayed area was approximately 50 per cent of that in the surrounding unsprayed area for two weeks after spraying, 60 per cent after three weeks, and 80 per cent after four weeks.

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RESEARCH ON MOSQUITOES BY THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE DURING 1950

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This is a brief summary of the research on mosquitoes carried on by the Bureau of Entomology and Plant Quarantine during 1950. The information has been made available to me by Alan Stone, taxonomist in the Washington, D. C., office; A. W. Lindquist, in charge of the Corvallis, Oregon, Laboratory; W. V. King, in charge of the Orlando, Florida, laboratory; and R. C. Roark, of the Beltsville, Maryland, Agricultural Research Center. The taxonomic investigations and those conducted at Corvallis and at the Beltsville Agricultural Research Center are financed by regular appropriations from Congress, whereas those at Orlando are financed by funds allotted by the Department of Defense.

TAXONOMY

Work on the taxonomy of mosquitoes consisted almost exclusively in assisting outside research workers with the loan of specimens, providing notes on types and other specimens in the United States National Museum, and giving aid to visiting workers. John Lane, from Brazil, spent nearly four months in Washington studying Neotropical mosquitoes. W. H. W. Komp and L. E. Rozeboom also spent some time in the Museum on various mosquito problems. Important loans were made to Walter J. LaCasse, P. F. Mattingly, R. M. Bohart, Robert Matheson, E. B. Thurman, R. F. Darsie, Jr., and W. B. Hull. The only important lot of mosquitoes sent in for determination was a fine collection of Iranian species from R. P. Dow. One paper, a description of the larva of *Culex foliaceus* Lane from the coast of Brazil, was published by Alan Stone.

INSECTICIDES

RESEARCH AT THE BELTSVILLE AGRICULTURAL RESEARCH CENTER

The recent development of allethrin—the so-called synthetic pyrethrum—by M. S. Schechter and F. B. La Forge is an

outstanding achievement. This material will undoubtedly serve as an excellent alternate for pyrethrum in controlling mosquitoes. As you know, the extract of pyrethrum flowers is an ingredient in liquefied-gas aerosols used for controlling mosquitoes indoors. This material produces a quick knock-down of flies and mosquitoes although higher concentrations of allethrin are required to give results comparable to pyrethrins.

Allethrin is a synthetic extract made wholly from materials produced in this country. It can be used in the same ways and formulations as pyrethrum extract is used. As a result of excellent cooperation and exchange of information between the Bureau's chemists, who developed a method of synthesis, and representatives of chemical industries, this material was made available in commercial quantities in a remarkably short time—about one year from the time of the first public announcement of the synthesis. Allethrin has been substituted for pyrethrum extract in aerosols now in use by the Armed forces.

BIOLOGY AND CONTROL

RESEARCH AT THE CORVALLIS, OREGON, LABORATORY

Use of Radioisotopes.—Tagging mosquitoes and other insects with radioactive phosphoric acid has proved useful in studies on the flight range of mosquitoes. Laboratory work has been conducted to determine the methods of getting the radioactive material into the insects, and the dosages necessary to produce enough radioactivity so that it can be detected with suitable instruments. As far as can be determined, mosquitoes carrying radioactivity of at least 5,000 counts per minute (cpm) are not injured and no shortening of life has been observed.

Adult *Aedes* mosquitoes showed measurable radioactivity when fourth-stage larvae were reared to adults in water containing approximately 0.0001 microcurie (μc) of radioactive phosphorus (P^{32}) per milliliter. A concentration of one-tenth this amount, or 0.00001 μc, gave significant readings in adults reared from second-stage larvae that had been exposed in the radioactive medium.

Detectable amounts of radioactivity were present in *Culiseta incidens* (Thom.) reared from eggs to adults at concentrations of 0.0001 μc or less of P^{32} per milliliter of water. This species was also used in a test which showed that the counts per minute in each insect decreased as the number of larvae per volume of treated water increased. When eggs of *C. incidens* were reared to adults in a pan containing soil, water, and enough P^{32} to give a concentration of 0.001 μc per milliliter of liquid, the counts per minute averaged 516 for the males and 957 for the females.

Synergists for Allethrin.—Approximately 150 compounds have been tested to determine whether they enhance the effectiveness of allethrin when used as a residual treatment against adults of *Aedes vexans* (Meig.) and *A. sticticus* (Meig.). Only 16 of the materials showed some promise as synergists, and none of these were especially outstanding.

Larvicides.—Laboratory testing of new materials for use as mosquito larvicides has been continued. Studies on the susceptibility of different instars of mosquito larvae to several insecticides showed that *Aedes dorsalis* (Meig.) required higher concentrations in all instars than did the *A. sticticus* and *A. vexans*.

Laboratory tests have been conducted with various emulsifiers and wetting agents to be used with oils as mosquito larvicides. At dosages of only 4 or 5 gallons per acre some of the combinations gave excellent results, especially on pupae.

Adulticides.—Limited daytime migrations of adult snow-water *Aedes*, as observed in the Cascade Mountains, have provided a vulnerable time when they may be controlled by aerial sprays. In the evening, however, between 8 and 9:30 p.m., their biting is severe and their flight habits so extensive that aerial applications over small areas are relatively ineffective. Residual treatments of DDT or lindane

applied to vegetation during the day, at the rate of 2 to 4 pounds of DDT or 3 pounds of lindane per acre, gave excellent protection to personnel within the local infested areas. However, no control was obtained during the evening. DDT mist sprays discharged upwind from a camp controlled mosquitoes during periods when they were not migrating but gave only fair protection during the evening migration period. Pyrethrum sprays gave good protection during the evening migration period, if the sprays were discharged frequently.

RESEARCH AT THE ORLANDO, FLORIDA, LABORATORY

Larvicides.—Field tests were conducted on small plots (mostly 1,000 square feet in size) to compare the effectiveness of DDT, dieldrin, lindane, toxaphene, chlordane, and parathion as oil solutions and as emulsions against larvae of anopheline mosquitoes (chiefly *Anopheles crucians* Wied.).

The materials were applied under favorable weather conditions with a specially constructed flit-gun sprayer at a uniform rate of 10.4 cc. per 1,000 sq. ft, and different dosages were obtained by varying the concentration of the material in the sprays. The dosages used in these tests ranged from 0.00035 to 0.025 with emulsions and from 0.0015 to 0.05 with oil solutions.

Dieldrin was the most effective of all the compounds tested. DDT and parathion were only slightly less effective than dieldrin, and both were considerably better than lindane, chlordane, or toxaphene. Four of the compounds were tested both as emulsions and as oil solutions, and all were more effective in the emulsion form. The difference was more marked with DDT than with the other three. Atomized fuel oil alone showed considerable toxicity to anopheline larvae but was highly erratic in different check plots.

Field tests were also conducted on small plots to compare the effectiveness of DDT, benzene hexachloride (40 per cent gamma isomer), dieldrin, and toxaphene against the larvae of salt-marsh mosquitoes (*Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.)) in the Cocoa Beach area, where DDT has been used extensively for several years, and in the Titusville Beach and Salt Lake areas, which have been treated only occasionally. The insecticides were applied at dosages ranging from 0.003 to 0.2 pound per acre with a hand-pressure sprayer equipped with a fine nozzle. Solutions were applied at the rate of 4 gallons per acre, and the concentration of insecticide was varied to give the desired dosages.

Dieldrin was slightly more effective than benzene hexachloride and toxaphene, and all three were considerably more effective than DDT.

Dieldrin showed about the same degree of toxicity to the two species in the test areas, whereas DDT appeared distinctly less toxic to *A. sollicitans* than to *A. taeniorhynchus*. Both DDT and benzene hexachloride were less effective against *A. taeniorhynchus* larvae in the heavily treated area (Cocoa) than in the occasionally treated area (Titusville), whereas with toxaphene the reverse was true.

Tests with Aerial Sprays.—Aerial larvicide tests were conducted on 40-acre plots with oil solutions of DDT, lindane, dieldrin, aldrin, toxaphene, and heptachlor, and with emulsions of lindane and heptachlor. The tests were run in areas that had been treated either intensively or only occasionally with DDT. Sprays were applied at the rate of 4 quarts per acre with a PT-17 airplane equipped with underwing spray booms.

In the occasionally treated areas, applications of 0.1 pound per acre of lindane, dieldrin, and heptachlor gave nearly perfect control of mixed populations of *A. taeniorhynchus* and *A. sollicitans*. Heptachlor and lindane at 0.05 pound per acre, and toxaphene at 0.2 pound per acre, gave close to 90 per cent control. Lindane emulsion at 0.025 pound per acre gave similar results, but oil solutions at this dosage were less effective. Aldrin at 0.1 pound per acre showed only 69 per cent control.

In two tests in the intensively treated areas, aldrin at 0.2 pound per acre was ineffective against *A. sollicitans,* and DDT at 0.4 pound per acre gave only 77 per cent control of a mixed population of *A. sollicitans* and *A. taeniorhynchus.* The fact that both materials at lower doses gave much better results in the occasionally treated areas indicated that the larvae in the intensively treated areas were much more resistant to these chemicals.

Preflood Treatments for Control of Salt-Marsh Mosquito Larvae.—Observations were made throughout the season on 11 salt-marsh plots to which mosquito larvicides had been applied as preflood or prehatching treatments in April and early May. The plots were each 2 acres in size, and the materials included in the tests were DDT, toxaphene, and dieldrin applied as wettable-powder dusts. Eight of the plots were located in the Cocoa Beach area, which had been intensively treated with DDT for several years and where the mosquito population has shown increased resistance to DDT. The other three plots were in the Titusville Beach area, which had been treated only occasionally. One or two untreated check plots were left with each group of test plots.

Preflood treatments of 0.5 and 1 pound per acre of dieldrin and toxaphene gave very good reductions of larval breeding through two to four floodings in the intensively treated area of Cocoa Beach, and were even more effective in the occasionally treated area of Titusville Beach.

DDT at 1 and 3 pounds per acre showed fair to moderate reductions through two to four floodings in the Cocoa Beach area, but was less effective than a 2-pound treatment in the Titusville area.

Resistance of Salt-Marsh Larvae to Different Insecticides.—Twenty-seven lots of salt-marsh mosquito larvae were tested in the laboratory for susceptibility to DDT, lindane, and toxaphene. Four of the lots were from an area that had been intensively treated with DDT in recent years and where the larvae showed considerable resistance to DDT in 1949; 23 lots were from occasionally treated areas. Three of the four lots from the intensively treated area showed a high degree of resistance to DDT, and one of the three also showed marked resistance to lindane. Three of the lots were slightly less susceptible to toxaphene than larvae from the occasionally treated areas, and the other was about equally susceptible.

Larvae from several occasionally treated areas showed equal susceptibility to DDT, lindane, and toxaphene, except for one lot of *Aedes sollicitans* which required relatively high concentrations of all the larvicides. A second lot of this species collected on the same marsh at the same time was more susceptible than most of the *A. taeniorhynchus* larvae, which predominated in most of the tests.

Dieldrin was the most effective material against larvae from intensively treated areas, and was more effective against larvae from occasionally treated areas than lindane or toxaphene. All three of these materials were somewhat better than DDT.

Adulticides.—Aerial spray tests with different insecticides against salt-marsh mosquito adults were conducted in the Cocoa Beach area, which had been intensively treated with DDT from 1945 to 1949 and with benzene hexachloride in 1950, and the Haulover Canal and Titusville Beach areas which have been treated occasionally with DDT. Treatments were made with a PT-17 plane, at the rate of 4 quarts per acre, at a swath interval of 100 feet. The concentration of the insecticides was varied to give different dosages. Most of the plots were 40 acres in size and so arranged that a number of tests could be run in a large area where conditions were similar.

Lindane and technical benzene hexachloride (40 per cent gamma isomer) as oil solutions gave excellent control of both species of salt-marsh mosquitoes at dosages of 0.1 and 0.05 pound of gamma isomer per acre in each of three different locations, and were more effective than lindane emulsion at a dosage of 0.05 pound. Lindane was also tested at 0.025 pound per acre, both as a solution and as an emulsion, but

did not give satisfactory control at this dosage.

Dieldrin at 0.1 and 0.15 pound per acre gave good to excellent reductions of both species of salt-marsh mosquitoes in intensively and occasionally treated areas, and gave good control at 0.05 pound per acre in the latter type of area but not in the former. Heptachlor showed almost perfect control at 0.05 and 0.1 pound per acre and appeared of considerable promise as a possible substitute for DDT for the control of salt-marsh species.

Tests Against Alaskan Aedes.—Three DDT formulations used in Alaska in 1949 were re-tested on large plots in 1950. These formulations included an airplane spray solution containing 20 per cent of DDT, 20 per cent of fuel oil, and 60 per cent of Paccosol; a 20 per cent DDT spray with 1 per cent of Triton B-1956 added; and an emulsifiable concentrate containing 20 per cent of DDT, 10 per cent of Triton X-100, and 70 per cent of Velsicol AR-50-G. The sprays were applied with a C-47 plane at rates of 25, 75, and 123 ml. per acre, or 0.1, 0.03, and 0.05 pound of DDT per acre.

All the formulations were highly effective at dosages of 0.03 and 0.05 pound of DDT per acre, larval reductions ranging from 92 per cent to 98 per cent. At a dosage of 0.01 pound, neither the 20 per cent spray with 1 per cent of a wetting agent nor the emulsifiable concentrate were very effective, but the latter gave slightly higher kills. The results of these tests did not permit a conclusion as to the most effective of the three formulations, but suggest that future evaluations should be made on the basis of somewhat lower dosages than were used in 1950.

Observations in large areas treated for mosquito control in 1948 and 1949 with accumulative totals of 0.3 and 0.7 pound of DDT per acre showed 99 per cent less larvae in 1950 than in adjacent untreated marshes. On the basis of pretreatment counts, the plot treated with 0.3 pound of DDT per acre in 1949 showed a larval reduction of 95 per cent in 1950. Similarly, the plot treated with 0.3 pound in 1948 showed a reduction of 86 per cent in 1949, and after additional treatment of 0.4 pound per acre in 1949 showed a further reduction in 1950 of 89 per cent, or 98.5 per cent of the original population in 1948.

DDT at 0.2 pound per acre was ineffective in the intensively treated area and gave only fair control in the other areas, but at 0.4 and 0.5 pound per acre gave satisfactory results even against the DDT-resistant adults in intensively treated areas. Toxaphene at 0.2 pound per acre was fairly effective in previously untreated areas but was not tested elsewhere. Aldrin at 0.1 pound per acre was ineffective.

Tests of Ground Fog Machines Against Alaskan Aedes *Adults.*—Extensive tests were conducted in Alaska in 1950 to determine the effectiveness and practicability of ground fog machines for the control of adult mosquitoes. In roadside tests, applications of 3.6 to 10 gallons of 10 per cent or 20 per cent DDT-oil solution per front mile (3 to 17 pounds of DDT) with a Tifa, Dyna-Fog and jeep-exhaust generators caused 81 per cent to 100 per cent reductions in adult biting rates within 2 to 4 hours after treatment. After 12 hours reductions were poor. Almost all the plots had sufficient adult populations within 24 to 60 hours to justify re-treatment, regardless of the amount of DDT applied. Repeated treatments of the same area apparently did not produce an effective residue, although a total of 0.5 to 0.8 pound of DDT per acre (based on a 120-yard swath) was applied in certain plots over a 2-week period.

Observations and counts indicated that with winds of 1 to 4 mph. the effective penetration of the DDT fogs was limited to about 600 feet, and was somewhat greater for the first 360 feet than the next 240 feet. Little or no reduction was obtained with winds greater than 4 mph. or during daylight hours. The optimum conditions for fog applications appeared to be between 9 p.m. and 2 a.m., when inver-

sion was favorable and winds were less than 4 mph.

Practical tests on the Big Delta Army Base indicated that considerable immediate relief from mosquitoes could be obtained with the Tifa and Dyna-Fog machines but even when adult mosquito populations were relatively low, as they were in 1950, treatments were needed almost daily to keep populations at a sub-annoyance level.

THE USE OF INSECTICIDES FOR MOSQUITO CONTROL IN CALIFORNIA

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Mosquito control in California now encompasses over 20,000 square miles, with Districts located throughout the length and breadth of the State. All control programs are primarily larviciding operations augmented by adulticiding through aerosol and spray applications. The Districts may be divided into those primarily concerned with salt marsh and coastal problems and those concerned with problems arising from an irrigation type agricultural economy. But this in no way seems to reflect the great diversity of breeding problems to which larvicidal applications must be adapted. These range from brackish and highly saline salt marsh along the coastal bays to clear river run-off in the interior, and from constantly flooded rice paddies in the Sacramento Valley to pasture, alfalfa and cotton lands, requiring repeated flooding and drying in the San Joaquin Valley. There are also the myriads of artificial containers collecting water from lawn sprinkling, etc. in the urban areas.

Aedes mosquitoes breeding in intermittent waters are a problem both in the salt marshes of the coastal areas and in the irrigated agricultural valleys. *Culex* mosquitoes are a problem throughout the state in any permanent or semipermanent waters. The *Anopheles* are a problem primarily in the north San Joaquin and Sacramento Valleys, breeding in extensive rice paddies and in the ditches carrying the water to and from these fields.

Before World War II diesel oil was the primary material used for a larvicidal spray. Some pyrethrum in various formulations was used for adulticiding when necessary.

When DDT became available in the spring of 1946 the mosquito control picture in California entered a period of rapid change. Economy of use made mosquito control possible in areas of low assessed value. Low phytotoxicity made it possible to spray among crops without danger of injury and the fact that emulsible concentrates easily mixed with any available water could be carried and applied at low gallonage per acre made it possible for highly mobile equipment to be developed which could operate, independent of any set supply source, for a full day's work, resulting in a considerable saving of labor time.

The first DDT used in any quantity in California was a 25 per cent emulsible concentrate purchased from War Surplus stock. This material formed an excellent, highly stable emulsion which proved to be very satisfactory for use as a larvicide both by ground and aircraft spray application. Wettable and dry base dusts and oil solutions were also tried by plane and ground application. Of these materials DDT emulsible concentrate was judged, from the viewpoint of effectiveness, economy and ease of handling, to be the best all around material for use in ground spray applications. For aerial spray work emulsions seem to be more satisfactory in some areas and oil solutions in others.

When supplies of this War Surplus

DDT emulsible concentrate ran out considerable difficulty was encountered in obtaining satisfactory larval kills with proprietary formulations then on the market. Investigation showed that this was due in part to the use of soap emulsifiers which reacted with alkalies so prevalent in much of California's soils but primarily due to the lack of stability of the emulsions formed. Special formulations, giving a very high degree of emulsion stability and compounded with stable emulsifiers, were found to be a requisite to good control.

During the 1947 mosquito season several of the Districts began experimenting with others of the chlorinated hydrocarbons in an effort to find more efficient and economical synthetic insecticides. This work has been carried on more or less continuously since that time. At present a special grant requested by the California MCA from Subvention Funds, administered by the California State Health Department, Bureau of Vector Control, provides for a program of screening and field testing any available new insecticides and the undertaking of any other basic investigations that seem to be indicated by field usage problems. This program is being carried on by a full time entomologist under the direction of the Kern Mosquito Abatement District.

In 1949 an apparent resistance to DDT appeared in a number of Districts in California. It is interesting to note that this condition seemed to occur only in the San Joaquin Valley south of Sacramento. This area is one having very high summer temperatures at which DDT loses its efficiency to some degree, its killing power being inversely proportional to temperature changes. It is hoped that accurate data as to this resistance will be obtained this year.

Dosage Rates

Before discussing the various insecticides which have been or are now in use it would be well to explain the wide variations in dosages used by various Districts. Salt marshes require much heavier doses of the chlorinated hydrocarbons than fresh water to obtain adequate kills. So also do waters containing high quantities of organic pollution such as some sewage effluent and wastes from food processing plants such as canneries and wineries. In these cases, where there is no danger of contact with warm blooded animals, sufficient material may be used to obtain a kill more economically than using diesel oil.

Insecticides Used

DDT emulsions have had the widest use of any of the larvicides used in California. They are used primarily as larvicides although occasionally may be used for adult kill as a spray and in aerosol units.

Dosages used for larviciding spray operation range from 0.17 lb. per acre in agricultural areas to 2.1 lbs. per acre for salt marshes. At the present time dosages in fresh water breeding are from 0.25 to 0.5 lb. per acre and in salt marshes from 0.96 to 2.1 lbs. per acre. All Districts in the San Joaquin Valley south of Sacramento and one District in the northern Sacramento Valley have indicated difficulties in killing with this insecticide at the present time.

DDT-oil solutions are used primarily for salt marsh control, larval control in highly polluted water and as aerosol for adult control. A few of the Districts use it for limited general control.

In the salt marshes 1 to 3 per cent Lethane is often added to the solution to insure better pupal kill. DDT dosages range from 0.96 to 2.4 lbs. per acre.

In highly polluted water dosages range from 0.96 to 4.0 lbs per acre.

In use as aerosol for adult control the percent solution varies widely from 2 per cent to 10 per cent. Opinion differs widely as to the efficiency of this method of control. Lethane or lindane may be added to the solution in varying amounts.

DDT 50 per cent wettable dust is used

in limited amounts. Pre-emergence treatment of riverbottoms for *Aedes vexans* has been successful using 1 to 1½ lbs. of DDT per acre. In the rice growing areas of the State 50 per cent wettable dust is added to seed rice to be planted by plane and put out in this manner at the rate of 1 to 2 lbs. per acre, giving control for three weeks.

Toxaphene is the next most widely used insecticide for mosquito control in California. It has replaced DDT in those areas where supposed resistance occurs with good success. It has not been found as reliable in salt marshes as DDT.

Dosages in fresh water range from 0.2 to 0.5 lb. per acre and may go as high as 1.0 lb. per acre for polluted water. Its short residual makes toxaphene less objectionable than DDT on pastures, etc., but limits use for pre-emergence treatment. The effectiveness of this material seems to be in direct ratio to the temperature.

DDD has been tried by a number of Districts with variable results. In general it seems to be effective in salt marshes at about ½ lb. per acre. One District reports poor kill at 0.66 lb. per acre.

In fresh water results have been variable. Some Districts report good results and some poor results. Generally, results have been less satisfactory in hot weather. The price has also been high. Rates for fresh water application where DDD is used range from 0.2 to 0.5 lbs. per acre.

BHC (10 per cent gamma) and lindane have also been tried by a number of Districts with variable results. No record of use in salt marshes is available.

BHC has been found objectionable due to its odor.

Dosages of lindane range from 0.02 to 0.24 lb. per acre.

This material is less satisfactory in hot weather and quite expensive.

Several other insecticides are under development at the present time for use as fresh water larvicides.

Aldrin has been field tried with predictable results at from 0.075 to 0.10 lb. per acre.

Heptachlor shows considerable promise at 0.075 to 0.1 lb. per acre but few trials have been made.

Dieldrin has received very limited trials. One District reports apparent resistance after 3 applications at 0.052 lb. per acre.

One District reporting apparent resistance to DDT tried a mixture of DDT and toxaphene in oil at 0.2 lb. DDT and 0.3 lb. toxaphene per acre with unsatisfactory results.

MOSQUITO CONTROL AT DEPARTMENT OF THE ARMY INSTALLATIONS

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Mosquito control is of vital importance at Department of the Army installations. The post engineer on the staff of the installation commander is responsible for the supervision and execution of control measures. These operations include application of larvicides, control of adult mosquitoes in buildings and on grounds, and the necessary drainage to remove potential breeding areas. Mosquitoes adversely affect Army operations by transmitting malaria, dengue, encephalitis, and other diseases. The pest species, if not controlled, will reduce efficiency and morale of military personnel.

Permanent Control. These methods include camp site location, control of potential breeding in streams, ponds, and other surface water on and around the reservation, filling and grading, ditching and the use of subsurface drains. These measures require considerable costs for labor and equipment. High initial costs are weighed against the cost of applying temporary measures such as larviciding and adulticiding with DDT and other insecticides during the contemplated occupancy of the post. Permanent programs are not recommended or approved until adequate surveys are made by personnel specially trained in entomology.

Temporary Control Methods. In post engineer operations emphasis is placed on the following temporary measures for mosquito control: application of larvicides in infested waters; applications of residual sprays in housing and training areas; and control of adult mosquitoes in outdoor areas with fog, mist, and hydraulic sprays.

Dispersal Apparatus for Ground Operations. Prior to the discovery and development of DDT, sprayers and dusters used by the Army were primarily commercial models purchased on the open market. Due to the urgent need for improved apparatus, research and development by the Army and by public and private agencies have produced marked improvements in the following types of apparatus: cylinder type compressed air sprayers; portable power sprayers; aerosol generators; mist blowers; and rotary hand operated and power dusters.

The most satisfactory compressed air sprayer available to the Army for applying insecticides in mosquito control consists of a steel cylindrical tank with a capacity of about 3 gallons. Accessories include spray gun and suitable nozzle and about 5 feet of oil resistant ⅜-inch spray hose. Weight of the sprayer containing 2 gallons of liquid does not exceed 27 pounds. The hand pump, filler opening, outlet tube, and pressure gauge are mounted in the head of the tank. The pump cylinder is 2 inches in diameter and about 16 inches long. Spring valves, flapper valves, and seats of the pump valve assembly are made of stainless steel.

A portable power sprayer issued to installations is a skid-mounted piston pump type gasoline engine driven unit. It consists essentially of a one cylinder gasoline engine, four stroke cycle, air cooled, capable of developing 1¾ h.p. at a governed speed of 2240 r.p.m. A V-belt drive transmits power to the pump. The unit mounted in a tubular frame is 34 inches in length, 17 inches wide, and 17 inches high. The net weight is about 195 pounds. Delivered capacities are affected by the operating pressure, size of nozzle opening, and spray used. The spray gun is made of corrosion resistant materials and equipped with satisfactory cut-off valves. The following nozzles are most satisfactory for use with spray gun: 1/16 inch, 5/64 inch, 3/32 inch, and 7/64 inch diameter holes.

The spray hose is ⅜ inch in diameter and oil resistant. With a pressure around 300 pounds per square inch and suitable adaptation of the spraying head, the spray droplets are finely broken up, and under favorable atmospheric conditions remain air-borne long enough to provide swath widths of about 600 feet. A high degree of adult mosquito control is obtained with this sprayer. Research and development work is under way on improved fog, mist and hydraulic type sprayer for large scale ground operations in mosquito control.

Dusts containing DDT are effective against *Anopheles* mosquitoes but the effects of treatments in the control of other species are in general disappointing. In breeding areas covered with vegetative growth, dusts are more effective than in areas relatively free of plant growth. A hand operated duster of the rotary blower type is used by post engineers. This duster has a cylindrical hopper with a rotary-type blower fan operated through a gear box by a hand operated crank. Accessories include carrying straps, discharge tubes, and nozzles. Net weight of the duster is about 12 pounds. The filler opening is 4½ inches square and constant agitation is provided to insure a uniform flow of dust from the hopper into the fan.

Evaluation and field tests of the commercially available fog spray equipment are being conducted prior to standardization of this type of equipment for issue. Operations to date show that the most effective fog spray for the control of adult mosquitoes has a droplet size ranging from about 16 to 60 microns. This type of fog applied with a machine moving at a speed of about 5 miles per hour has not injured foliage, and produces the minimum of spotting on automobiles, buildings, and clothing. Applications are most effective when made during early morning or late afternoon and with wind movement not exceeding about 7 miles per hour. Housing and training areas are best treated by travelling passable terrain, roads, and streets at a speed ranging from 5 to 10 miles per hour with a swath width of about 300 feet.

Mist blowers are also being evaluated at Army installations prior to standardization and procurement for general issue. The most effective mist blower for mosquito control produces an atomized spray with the droplets having a mass average diameter of about 50 to 100 microns. Mist sprays will rise and spread best on calm, warm, and dry days with some upward air currents present. With wind movement ranging from 5 to 10 miles per hour, effective swath widths of 800 feet have been obtained in the application of mosquito larvicides. The dosage rate per acre does not exceed .3 pound of DDT or .1 pound of lindane.

Frequency of Application of Control Measures. Surface waters that contain mosquito breeding receive an application of mosquito larvicide at intervals of 7 to 21 days as determined by records of mosquito traps and larval dips. Control of mosquito adults in living quarters and other permanent buildings is accomplished with residual sprays applied for household pests. The residual spray is usually 5% DDT in kerosene applied at intervals of 30 to 60 days during warm weather with a dosage rate of about one quart of the spray to 250 square feet of the inside surfaces covered. Adult mosquitoes in training and recreational areas are controlled with fog sprays applied at intervals of 7 to 14 days and mist sprays applied every 14 to 21 days as determined by mosquito densities, during the breeding season.

Coordination with Other Government Departments. Coordination is maintained with other departments of the Government, especially the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, and the United States Public Health Service (for results of research on mosquito control). This cooperation includes exchange of information, and joint participation in the development of equipment and field operations for mosquito control.

SOME ENTOMOLOGICAL ASPECTS OF A FLOOD EMERGENCY

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From time to time persons charged with mosquito control planning are faced with the problem of establishing an emergency program to abate the hordes of mosquitoes occasioned by a flood. Often the communities involved have not conducted routine mosquito control nor is information available on the mosquito fauna. Consequently, when entomological information is available from a flood site, it seems desirable to pass it on to others who may face a similar problem.

The city involved in the mid-summer flood emergency which provides the subject of this paper was Great Bend, Kansas. It is a city of about 11,000 population located near the center of the state in the broad, flat flood plain of the Arkansas River. Great Bend is bordered on the south by the Arkansas River and on the north by Walnut Creek. Walnut Creek has two branches, Dry Walnut, at the north edge of the city and Wet Walnut, two to three miles north of the city.

The flood involved both branches of Walnut Creek although Dry Walnut was the principal contributor to the inundation of the city. The flooded area was principally grassland. The Arkansas River, fortunately, stayed within its banks although it lacked only two inches of overflowing. Had the Arkansas overflowed along with Walnut Creek, the entire city would have been inundated.

We have been engaged in Kansas in surveying the mosquito fauna in our principal river basins. One of our light traps had been placed near the southern city limits of Great Bend approximately six weeks before the flood. It was operated nightly throughout the flood and for nearly two months after the recession of the waters.

Mosquitoes were rather scarce throughout June and July. Almost all of the specimens collected were *Culex tarsalis,* a common mosquito in the general area. During the last week in July, heavy rains fell and at the end of the month the flood occurred. About seven days later the trap catches increased abruptly as did mosquito annoyance. The flood waters subsided from the city during this period, but the area between Wet and Dry Walnut Creeks remained inundated until near the end of August. A large part of the catches remained *Culex tarsalis* although *Aedes vexans, Aedes dorsalis* and *Psorophora signipennis* occurred in significant numbers. Two weeks after the flood, the trap catches increased abruptly. The highest post-flood catch was more than two hundred times greater than the average catch for the pre-flood period.

At this point control measures were undertaken. The control consisted of fogging the entire city in one night with 5 per cent DDT in oil. The equipment used was a TIFA fog generator. This operation resulted in an overnight reduction in trap catches of about 80 per cent. This level of control persisted for four days. The fogging was then repeated and a satisfactory reduction was again achieved. Although it is fortunate that the fogging was effective, it seriously interfered with the data from the standpoint of observing how long the outbreak would have lasted in the absence of control.

It may be noted that throughout the flood period the bulk of the mosquitoes were *Culex tarsalis.* Night biting collections supported the evidence of the light trap in this particular. After the recession of the flood *tarsalis* declined in numbers. Several species of *Aedes* and *Psorophora* and *Culex quinquefasciatus* and *pipiens* became the predominant mosquitoes. *Anopheles quadrimaculatus* first appeared in early September, but never reached significant numbers. Prior to the flood only four species had been collected. During

the height of the post flood outbreak, twelve species occurred. Most of the newcomers were *Aedes* and *Psorophora.* Nearly all of these species persisted for the remainder of the active breeding season, appearing graphically as regularly spaced peaks about a week apart. During the entire season, sixteen species were collected. These include six species of *Culex,* two of *Anopheles* and four each of *Aedes* and *Psorophora.*

In attempting to draw conclusions from the light trap records, the following generalizations might be mentioned:

1. The tremendous expanses of potential breeding areas provided by floods can result in abnormal numbers of mosquitoes.
2. The variety of ecological situations provided by flooding and the subsequent recession of the water increases the number of species encountered. The components of the fauna undergo progressive change as the water recedes and new ecological situations are created.
3. If the predominant preflood species is capable of breeding under the ecological conditions presented by flooding, it will continue to be predominant during the flood period. *Culex tarsalis* is, of course, readily adaptable to breeding under flood conditions.
4. Peaks, or waves, of mosquito abundance may occur regularly for some time after the highest peak of mosquito abundance. These peaks are spaced approximately the length of a mosquito generation apart. Apparently these are reflections of the principal peak.
5. Effective emergency control can be obtained by city-wide fogging. This control is temporary and must be repeated if satisfactory levels of mosquito abundance are to be maintained.

STRIP SPRAYING BY HELICOPTER TO CONTROL BLACKFLY LARVAE

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Investigations in many areas have confirmed the reports of Fairchild and Barreda (1945) that DDT will control blackfly larvae. Gjullin *et al.* (1949) showed that DDT and a number of other insecticides were effective when applied to Alaskan streams with various types of ground equipment and by aerial applications. Hocking *et al.* (1949, 1950) working in Churchill, Canada, showed similar results. Other workers (Kindler and Regan, 1949; Hocking, 1950; and Goulding and Deonier, 1950) have also obtained good results with various formulations of DDT and other new organic insecticides. The earlier aerial spray data were obtained largely from plots originally laid out and used for mosquito control experiments or for forest insect control (*e.g.* gypsy moth), or from selected sectors of streams sprayed for blackfly control. Arnason *et al.* (1949) in Canada obtained complete control for 17 miles downstream when a large amount of DDT was applied across one sector of the Saskatchewan River.

From the information cited it would appear that it should be possible to

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obtain control of blackfly larvae in a large area by applying DDT from the air in swaths flown at regular intervals over the plot instead of trying to treat each stream individually or giving a complete spray coverage to the entire area. By this method it might be economically feasible to treat large blocks of land infested with blackflies in areas where rough terrain and the large number of small streams make ground methods impractical.

An unusual opportunity for observing the results of this method on a practical basis in an area where the seasonal history of blackflies has been observed for many years was presented in the summer of 1950. Two years previously the Town of Webb, which includes Thendara, Old Forge, Eagle Bay, Big Moose and several other communities in the central Adirondacks of New York State, had inaugurated a blackfly control program. Blackflies were so numerous and such vicious biters in this region that recreational activities, on which the area now largely depends for its economic wellbeing, were virtually impossible in the spring and early summer until blackfly control was instituted on a regular basis. In 1948, DDT fogging from a helicopter was undertaken over an area of some 4,000 acres in the vicinity of Old Forge, for the control of adult blackflies. Although a conspicuous abatement of the blackfly nuisance occurred, this method, besides being topical and temporary, was also expensive. Therefore, investigation of other methods continued, and in 1949 several of the communities in the Town treated many streams with DDT impregnated plaster blocks, as had been suggested by Dr. Gustave Prévost, for the destruction of blackfly larvae. Although the block treatments did result in the killing of many blackfly larvae, and were considered by the residents to have contributed greatly to the further reduction of the blackfly nuisance, it was not possible in 1949 for the entomologists who were watching the operations to evaluate the two methods from a comparative standpoint, nor to study the effects upon other stream and forest fauna as critically as could be desired. The block method, although apparently cheaper, was actually rather expensive in terms of time and labor, since it was planned to treat all of the streams, even the smallest, up to their headwaters in an area of over 100 square miles. Therefore, in 1950, in view of the success of the aerial larviciding treatments cited above, it was decided to reserve a portion of the area of approximately equal size to be treated for a test of the swath method of aerial larvicide application.

The Town of Webb arranged to have the spraying done by helicopter. The Army Quartermaster Corps furnished the spray material; the authors of this paper supervised the operations and made the observations herein recorded.

The area selected to receive the spray was a wilderness area northwest of Thendara which was apparently responsible for the production of a large proportion of the blackflies that plagued the villages of Thendara and Old Forge. The area was laid out on the map in the form of a trapezoid in such a way that swaths flown from the southwest to the northeast a quarter of a mile apart would cross most of the streams at least once near their headwaters. The plot averaged about 12 miles long and 2¾ miles wide. The terrain was rough with an approximate range of elevation of 1700 to 2400 feet. The area was heavily wooded but the foliage had not developed at the time of spraying.

The plot was sprayed in the late evening of May 2 and the early morning of May 3, 1950. The pilot flew swaths about 100 feet wide and a quarter of a mile apart the length of the plot. The swath lines were flown by following a marked topographical map and a compass. Wind conditions were favorable, being no more than 5 to 10 miles per hour during the last two swaths, and less during the others. Good inversion prevailed except during the last two swaths, when, due to air movement, the conditions were isothermic. Flight was 25 feet or more above the trees.

The spray was delivered from a helicopter provided with a pressure spray

system equipped with two nozzles which delivered 0.35 gallon each per minute at 60 pounds pressure. By flying 60 miles per hour a dosage of approximately 0.1 pound per acre *over each swath* was delivered. The spray consisted of 20 per cent DDT, 20 per cent fuel oil and 60 per cent auxiliary solvent. A total of 140 gallons were used to swath-spray the approximately 40 square miles.

Results: Eighteen observation stations were established at random across the width of the plot and scattered from one end of the plot to the other. Blackfly larval populations were sampled at these stations by counting and estimating the number of larvae per square foot of surface of either submerged rocks or of vegetation or of both. Pre-treatment populations in 16 of the streams ranged from 50 to 100 per square foot and in two locations only 15 to 25 per square foot.

Prosimulium hirtipes (Fries) constituted 74 per cent of the population, and *Eusimulium mutatum* (Malloch) 24 per cent. *Simulium venustum* Say comprised the remaining 2 per cent. Most of the larvae were in the last instar except at one station, where they had begun to pupate.

Four days after treatment no blackfly larvae could be found at 7 of the 18 stations. At two stations, control was estimated to be better than 95 per cent. One station showed no reduction and one station only 50 per cent reduction. The estimated total reduction for all 18 stations was about 85 per cent.

Observations were made also on the numbers of aquatic arthropods in the stream beds and on the numbers carried downstream at various intervals of time after treatment. In one stream in the center of the plot (Indian Creek) regular observations of all stream organisms were made at weekly intervals throughout the summer, beginning before the treatments. Blackfly larval populations were estimated by counts of larvae on stones in rapids and on trailing grasses, and a square foot bottom sampler was used to obtain counts of the bottom fauna which normally exist in large numbers under stones and in bottom debris. Samples of the organisms carried downstream were taken in cross-stream nets and in square-foot nets placed in narrow sections of the stream for 5-minute periods at weekly intervals.

The numbers of blackfly larvae per stone or grass blade before treatment varied upwards from 100. By one day after treatment they had disappeared completely from the grass blades, which remained uninfested thereafter for 36 days. Larvae on stones were reduced from 100 per stone to less than 3 per stone, the complete reduction not occurring until two or three days later than the complete disappearance from the grass blades.

In one of the nets mentioned above, blackfly larvae and other arthropods appeared in increased numbers a few minutes after a swath which centered about 50 feet upstream from the net. Blackfly larvae continued to come downstream for 72 hours after the application. This extended time was caused partly by the fact that larvae were delayed in arriving at the sampling point because of the distance upstream from which they came, or because they were temporarily sidetracked into swirls and pools.

Other aquatic arthropods were disabled and washed downstream also, but in smaller numbers, for about the same period of time as the blackfly larvae. With bottom sampling methods, no measurable reduction of arthropods other than blackfly larvae was observed. In fact, a week after treatment, judged from bottom samples, the arthropod population, excluding blackfly larvae, showed an increase, or no noticeable change, averaging 41 per square foot before treatment and 45 per square foot a week after treatment. Thereafter there were fluctuations both above and below the pre-treatment level, apparently independent of the treatment.

Trout, both above and below seven inches, were observed in Indian Brook both before and after the helicopter treatments, and afterwards throughout the summer. Amphibia, including both frogs and salamanders, were numerous and apparently unaffected by the treatments.

No attempt has been made here to present the aerial dosages in terms of parts per million. The impossibility of arriving at an accurate figure applicable to the extreme range in flow and size of the treated streams is obvious. A per unit area dosage is more easily described and followed under the conditions involved in routine control work. By the swath method of application the dosage is, to a certain extent, automatically adjusted to the size of the stream.

Blackfly larvae appeared in some of the block-treated streams about two weeks after the treatment, but the species represented were *Simulium venustum* Say, *S. perissum* D. and S., and *S. vittatum* Zett., not *Eusimulium mutatum* or *Prosimulium hirtipes,* the species that had been present in the spring, before treatment. The streams were again infested the fall after treatment with the latter species.

Discussion. It was observed that blackfly larvae at the dams at lake outlets were not materially reduced in numbers. The pilot shut off the spray when passing over large lakes to avoid possible damage to fish. As a result, the dosage of spray reaching the larvae at the outlets was insufficient to be effective, since the minute amounts per unit area deposited on the streams flowing into the lakes suffered further extreme dilution from these large bodies of water. Special attention should be given in the future to such areas.

The two streams in the sprayed areas showing little or no reduction in larvae were short brooks, and ran between and parallel to the swaths. It was thought that eighth-mile swaths at the same dosage per acre might not have missed the short parallel streams and might have treated the area adequately.

With respect to the ultimate objective of the treatments, that is, the abatement of the blackfly nuisance in the populated areas, it is more difficult to make a critical analysis. It was agreed by all concerned, including entomologists and the public at large, that the control measures accomplished a significant degree of blackfly control. It was demonstrated that either method alone—fogging, DDT plaster blocks, or aerial spraying—would at least partly accomplish the objective. However, the populated areas where all three methods were used together experienced the most pronounced relief, and it is therefore difficult to assign the proper relative values to the several treatments. Since the aerial fogging is the most expensive, the logical next step is to omit this treatment and determine whether improved stream treatment techniques, supplemented by local ground fogging, can be made to accomplish satisfactory blackfly abatement.

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ARTICLES

TOXICITY OF ALLETHRIN TO MOSQUITOES, AS COMPARED WITH PYRETHRINS *

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The synthesis by Schechter, Green and LaForge (1949) of organic esters analogous to cinerin, one of the toxic constituents of pyrethrum, has opened a new lead toward the preparation of insecticides relatively non-toxic to higher mammals (Starr et al., 1950). Because of the present high cost of pyrethrum this achievement has aroused great interest among insecticide manufacturers and scientific investigators. One of these synthetic compounds is now manufactured commercially under the assigned name "allethrin."

Chemically, allethrin has been designated as dl-2-allyl-4-hydroxy-3-methyl-2-cyclopentene-1-one ester of dl-cistrans-chrysanthemum monocarboxylic acid (Schechter, et al., 1949). Commercial allethrin is about 92 per cent pure; high boiling, clear yellow liquid; sp. gr. 1.005, refractive index 1.504 at 20° C.; insoluble in water, but completely miscible with petroleum distillates (McNamee, 1950).

Federal and state agencies as well as commercial laboratories are now engaged in testing allethrin on different species of insects, in comparison with pyrethrins. Gersdorf (1949), reported this compound to be more toxic to houseflies than the natural pyrethrins. Stoddard and Dove (1949) indicated that allethrin is about equal to pyrethrins in toxicity to houseflies, but is considerably less effective on other insects, including German cockroach, confused flour beetle, and nine species of truck-crop insects. Piquett (1949) showed that allethrin is less effective on adult males of the American cockroach than is pyrethrins. By the addition of certain synergists at the ratio of 5 to 1, the effectiveness was increased to that of pyrethrins. Jones, Schroeder and Incho (1950) tested allethrin with and without synergists in comparison with pyrethrins on houseflies, German cockroaches, rice weevil, confused flour beetle, Mexican bean beetle and other insects. From their preliminary studies they concluded that though "the effectiveness of allethrin and pyrethrins with synergists varies with the synergist employed, and insect species; combinations of allethrin with synergists show a lower order of insecticidal effectiveness than similar combinations of pyrethrins with the same synergists." Nast (1950) summarized results from several laboratories with allethrin on houseflies and roaches. On flies, allethrin was almost, but not quite, as effective as pyrethrins. On roaches "it seems safe to conclude that from two to four times as much allethrin as pyrethrins is required to obtain the same kill." On the other hand, residual tests, conducted on glass panels treated with acetone solutions of the toxicants and exposed to houseflies 8 days later, indicate that the residue from allethrin is superior to that of pyrethrins.

The writer became interested in investigating the toxic properties of allethrin to mosquitoes, as a possible substitute for pyrethrins in the New Jersey Mosquito Larvicide, which is essentially a kerosene pyrethrin emulsion (Ginsburg, 1930, 1939). Accordingly, laboratory tests were conducted with allethrin, in comparison with pyrethrins, as colloidal dispersions and oil-emulsions on larvae, pupae and emerg-

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ing adults of *Aedes aegypti*. Allethrin was also tested in combintaion with several synergists.

MATERIAL AND METHODS

A commercial sample of allethrin, about 92 per cent pure, and a concentrated extract of pyrethrum, containing 22.4 per cent actual pyrethrins, were employed in preparing the desired formulations.

Tests on larvae and pupae.—For the colloidal dispersions, 1 ml. of acetone containing various concentrations of the toxicants was stirred in 100 ml. distilled water in beakers containing either 50 third and fourth instar larvae or 25 pupae. The emulsified larvicides were prepared by incorporating various concentrations of either allethrin or pyrethrins in kerosene and emulsifying the solutions with sodium lauryl sulfate. The concentrated emulsions contained 66 per cent kerosene and desired amounts of toxicants; 33.5 per cent water and 0.5 per cent emulsifier. Before testing, the concentrated larvicide was thoroughly mixed, diluted with nine parts of water and applied at the rate of 25 gallons per acre (2.5 gal. concentrate). The tests with the emulsion were carried out in porcelain dishes containing 500 ml. of water and larvae or pupae. The area of the water surface in the dish was approximately 0.27 sq. feet. The tests were run for 24 hours, in three or four replicates. During this period some larvae had pupated, and the live pupae were included with the surviving larvae. Likewise, emerging adults in the pupae tests were counted with the live pupae.

To ascertain whether some of the known synergists may enhance the toxicity of allethrin to larvae, the following three compounds, which had been reported to synergize pyrethrins on flies and other insects, were selected:

1. Piperonyl butoxide (3,4-Methylenedioxy benzyl-butyl diethyleneglycol ether)
2. N-Propyl Isome (di N-propyl maleate iso-safrol condensate)
3. Sulfox-cide (n-Octyl sulfoxide iso-safrole)

The synergists were incorporated in the kerosene before emulsification at the ratio of 5:1, that is, for each part of allethrin, five parts of synergist were added. Two concentrations of allethrin, 0.033 per cent and 0.0165 per cent, which when tested without synergists gave less than 100 per cent larvae mortality, were used.

Emerging mosquito adults.—It had been observed by the writer in previous laboratory and field experiments that mosquito adults emerging in waters sprayed with low dosages of pyrethrum larvicide, even sublethal to larvae and pupae, become affected to the extent that they could not fly away, resulting in a high percentage of mortality. It became of interest to ascertain whether allethrin functions in the same manner. Comparative tests of pyrethrins and allethrin were, therefore, made under identical laboratory conditions. Concentrations of toxicants, ranging from 0.1 down to 0.0125 p.p.m. were colloidally dispersed in beakers of water containing pupae. Observations on the emerging adults were made over a period of 40 hours after treatment.

RESULTS

The average results are presented in four tables. The data in Table 1, from colloidal solutions, indicate that allethrin is decidedly less toxic than pyrethrins to larvae and pupae. Based on the LD-50, pyrethrins appear to be 2.5 and 4 times as toxic as allethrin to larvae and pupae respectively.

TABLE 1. Comparative Toxicity of Allethrin and Pyrethrins in Colloidal Solutions to Mosquito Larvae

Toxicant Tested	*Dilutions in p.p.m. for Mortalities of*			
	50%		100%	
	Larvae	*Pupae*	*Larvae*	*Pupae*
Pyrethrins	0.033	0.05	0.10	0.125
Allethrin	0.083	0.20	0.25	0.50

Analogous results were also obtained with the oil-emulsion larvicide. The percentage of allethrin in the concentrated larvicide required to give 100 per cent dead larvae was 0.134, or twice the amount of pyrethrins (Table 2). However, the

TABLE 2. Comparative Toxicity of Allethrin and Pyrethrins in Oil Emulsions to Mosquito Larvae

% *toxicant in concentrated emulsion*		*Average % mortality in 24 hours*
Pyrethrins	*Allethrin*	
0.0335	—	98
0.0670	—	100
—	0.0335	75
—	0.0670	97
—	0.1340	100

effect of allethrin on mosquito adults emerging from pupae in waters receiving sublethal doses of the toxicants (Table 3)

TABLE 3. Mortalities of Adult Mosquitoes Emerging from Pupae, Subjected to Sublethal Dosages of Pyrethrins or Allethrin

Series No.	*Toxicant p.p.m.*		*% Dead Pupae*	*Adult Mosquitoes*	
	Pyrethrins	*Allethrin*		*No. Emerged*	*% Dead*
20	0.05	—	56	4	100
40	0.025	—	18	28	100
80	0.0125	—	6	44	87
10	—	0.10	0	50	100
20	—	0.05	0	42	90
40	—	0.025	5	48	82
80	—	0.0125	5	40	70
Check	—	—	4	48	8

seems to be only slightly lower than that of pyrethrins. In concentrations of 0.0125 p.p.m., both insecticides were virtually nontoxic to pupae, but the percentage of dead adults was 87 per cent for pyrethrins and 70 per cent for allethrin.

None of the three synergists incorporated in the larvicides showed any significant increases in the toxicity of allethrin to larvae (Table 4). At concentrations of

TABLE 4. Toxicity of Allethrin in Oil Emulsions Containing Various Synergists to Mosquito Larvae

% Allethrin in the concentrate emulsion	*Synergist added (5:1)*	*Average % Mortality in 24 hours*
0.033	none	75
0.0165	none	67
.033	pip.-butoxide	87
.0165	pip.-butoxide	63
.033	n-propyl isome	93
.0165	n-propyl isome	76
.033	sulfox-cide	95
.0165	sulfox-cide	65

0.0165 per cent of allethrin, the mortalities were 67 per cent without synergist, 63 per cent with piperonyl butoxide, 76 per cent with n-propyl isome and 65 per cent with sulfox-cide. With twice the above concentration of allethrin (.033 per cent), some increases in mortality of larvae in the presence of the synergists were observed, but in no case was 100 per cent kill obtained. The results indicate that the toxicity of allethrin to *Aedes aegypti* larvae was not materially increased by the addition of any one of the three synergists here tested in 5:1 ratios.

In general, the results show that although allethrin possesses high toxicity to *Aedes aegypti* it is decidedly less effective than pyrethrins.

SUMMARY AND CONCLUSIONS

Laboratory tests were conducted with allethrin in comparison with pyrethrins in form of colloidal water solutions and oil emulsions on *Aedes aegypti* larvae, pupae and emerging adults. A study was also made of the effect of the three synergists piperonyl butoxide, n-propyl isome and sulfox-cide on increasing the toxicity of allethrin to mosquito larvae. The results brought out the following information:

1. Allethrin possesses high toxicity to mosquitoes, but is less toxic than pyrethrins. Measured in p.p.m., the LD-50 on mosquito larvae was .033 for pyrethrins and .083 for allethrin.

2. In colloidal water solutions, pyre-

thrins were 2.5 and 4 times as toxic to larvae and pupae respectively as allethrin.

3. In oil emulsion-larvicides, applied on water surfaces, pyrethrins also exhibited higher toxicity to larvae than allethrin.

4. The addition of synergists did not materially increase the toxic properties of allethrin to mosquito larvae.

5. Allethrin was nearly as toxic as pyrethrins to mosquito adults emerging from pupae subjected to sublethal dosages of the toxicants.

6. As a substitution in the New Jersey Mosquito Larvicide, the amount of allethrin required to kill 100 per cent mosquito larvae is approximately twice that of pyrethrins.

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MOSQUITO CONTROL TECHNIQUES FOR CONTROL OF *HIPPELATES* SPP (Diptera: Chloropidae)

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During the spring of 1948, tests were conducted in the Coachella Valley of California in order to determine the effectiveness of presently used mosquito control measures in the control of *Hippelates* spp. These gnats, principally *Hippelates pusio* Loew, for many years have been a plague to the residents of the Valley. They have been implicated in the transmission of follicular conjunctivitis which is endemic in the area (Herms, 1939). This disease is particularly prevalent among pre-school and school-age children, although adults are sometimes victims of this malady.

In addition to the public health implication of the problem, the gnats are an economic liability because of their annoying habit of swarming about one's head, particularly the eyes and ears. As a result, much time is lost by agricultural workers, processors of fruits and vegetables, and others accessible to the gnats. In the area, a winter resort section, tourist trade has been discouraged by the swarms of these gnats and real estate values have suffered as a consequence. The predominant agricultural products are dates, grapes, grapefruit, and truck crops.

Although much work has been done over the years in the Valley aimed at the control of *Hippelates pusio* and related species, little success has been realized. In reviewing the existing literature, little information was available which could be used as a guide for this investigation. The principal lacuna was in the realm of biological and ecological information. In order to attempt to remedy this situation, biological studies were begun toward the end of the tests which are discussed below. These studies will be reported at a later date.

Herms (1928) states that a study project on *Hippelates* spp. began in the Coachella Valley in the summer of 1926. His first publication (Herms, 1926) on the subject of *Hippelates* spp. in the Valley stated that their bionomics were unknown and that the residents of the area asserted they had been increasingly disturbed by the gnats for ten or more years.

Burgess (1935) reported on the biology of *Hippelates pusio* and recommended certain control procedures. Some of these recommendations have been followed by the Coachella Valley Mosquito Abatement District through the years subsequent to 1935. To a great extent they have been dependent upon trapping techniques utilizing decaying liver as bait. This putrescent material is so unpleasant as to render the use of traps near habitations undesirable. Such trapping methods serve only to reduce the gnat population by a very limited amount in relatively small areas. Herms and Burgess (1930) reported on the immature stages of *Hippelates pusio* with a description of its life history. Herms (personal communication, 1948) stated that to his knowledge immature stages of *Hippelates* spp. had not been taken from natural habitats in the Valley, but that work on the life cycle had resulted from observations of specimens reared in the laboratory.

Hall (1932) reported on breeding media suitable for the laboratory rearing of *Hippelates pusio* and on the economic and public health problem caused by their presence in the Coachella Valley.

Sabrosky (1941) issued a provisional key to the genus *Hippelates* occurring in the United States. Bigham (1941) reported on his investigation of the *Hippelates* problem in the southeastern states. Tests that he conducted showed that adjustments in agricultural practices could reduce materially the gnat infestation in the areas of Florida which were so plagued. Similar observations were made by Parman and Burgess (1931) in the Coachella Valley.

The residents of the Coachella Valley, through the Board of Trustees of their Mosquito Abatement District, requested assistance from the Bureau of Vector Control in attempting to solve this problem. An attack was launched in order to obtain data as to the effectiveness of existing mosquito control measures when applied against the gnats. This decision was made with the full realization that the experiment might be unsuccessful in view of the limited knowledge of the biology of the species present in the Valley. It was hoped, however, that during the course of the study a method could be demonstrated to the District whereby the gnats could be abated.

With this objective in mind, the decision was made to conduct a series of tests using DDT as the toxicant, with the following methods of application: airplane aerosol and spray; ground aerosol, dust, and spray. In order to evaluate the relative effectiveness of these methods it was necessary to establish trapping techniques and to select the areas to be treated. It was necessary in the selection of areas for treatment to attempt to choose areas large enough to afford satisfactory tests and sufficiently isolated to prevent clouding of results through infiltration of gnats from surrounding territory.

In order to attain these prerequisites, six areas of varying size were chosen. In addition, six check areas were selected which, as nearly as possible, had similar soil conditions, agricultural practices, and crops. These untreated check areas were to be maintained as indices to the natural fluctuations of gnat population.

Throughout these areas bait traps similar

to those used by Burgess, utilizing liver, urea, and water as bait, were placed so that the densities of the gnats could be checked. The locations of the traps were randomized in an attempt to obtain statistically valid samples. The specimens were collected routinely at 24-hour intervals, and the gnats counted and identified in the laboratory.

An agricultural power duster of the orchard type was used to apply DDT dust in the ground pre-emergence tests. The ground spray was applied with both compressed air type and direct gear drive type power sprayers. These were fitted with nozzles delivering a coarse spray which was applied directly to the ground and all vegetation up to approximately 18 inches high. The ground aerosol treatments utilized both a jeep venturi aerosol and a commercial thermal aerosol. The airplane aerosol equipment used was modeled on the type developed by the TVA and mounted on a PT-17 plane. The spray equipment was of the boom type, mounted beneath the wings, with nozzles attached to the boom. Pressure was supplied by a wind-driven, propeller-equipped gear pump mounted on the wing. The spray equipment was mounted on the same plane that carried the aerosol equipment.

RESULTS AND DISCUSSION

Airplane Treatments

The Oasis area was sprayed on the 19th, 20th, 21st of April at the rate of 0.4 lb. of DDT per acre. The Indian Wells area was aerosoled on April 25 and 26, at the rate of 0.1 lb. of DDT per acre, and again on May 10, 11, and 12, with 0.3 lb. of DDT per acre. This latter aerosol treatment was necessary as the discharge rate of the first aerosol treatment was but one-fourth the rate anticipated.

Since it took several days in each case to treat any one of the areas, with only a portion of each plot treated on any one day, a reduction following completion of treatment, rather than a reduction at the time of treatment, would indicate control. No significant control was obtained. Any variation of trap collections between different areas was explained on the basis of natural phenomena. This is made evident on analysis of pre-treatment data. There were numerous instances when the Oasis area had a much larger count than the Indian Wells area and also when the reverse was true.

Ground Application

A tabulation was made of the trap collections of the gnats following the treatment of the Zimmerer area with 0.5 per cent DDT emulsion spray at the rate of one pound of DDT per acre, using ground spray equipment, and compared with those from a nearby untreated area of the same size and same type of vegetation. Apparently there was a small degree of control for a period of at least 27 days. As the season progressed the average number of gnats collected became more nearly equal in each plot, thus indicating a break-down in control.

Brown's area was treated with 10 per cent dust at the rate of one pound of DDT per acre. Brown's area is compared with a similar neighboring area. The results indicate a small degree of control for about a week. However, these data are inconclusive because no trap records were kept for the untreated area until six days after the treated area trap records were started. Later collection records definitely indicated that no control was obtained.

For both sprayed and dusted plots the data show that control operations should have been started later in the year, probably around May 15, when the gnats were more numerous.

At Duncan's area there was a sharp decline in the number of gnats collected for three days after the treatment, which was a ground aerosol application of 5 per cent DDT in diesel oil. This drop was followed by a sharp rise in the number of gnats collected. On analysis, however, it appeared that the decline and subsequent rise corresponded closely with the rise and decline of the temperature (Figure 1) and the average counts of all traps. This drop

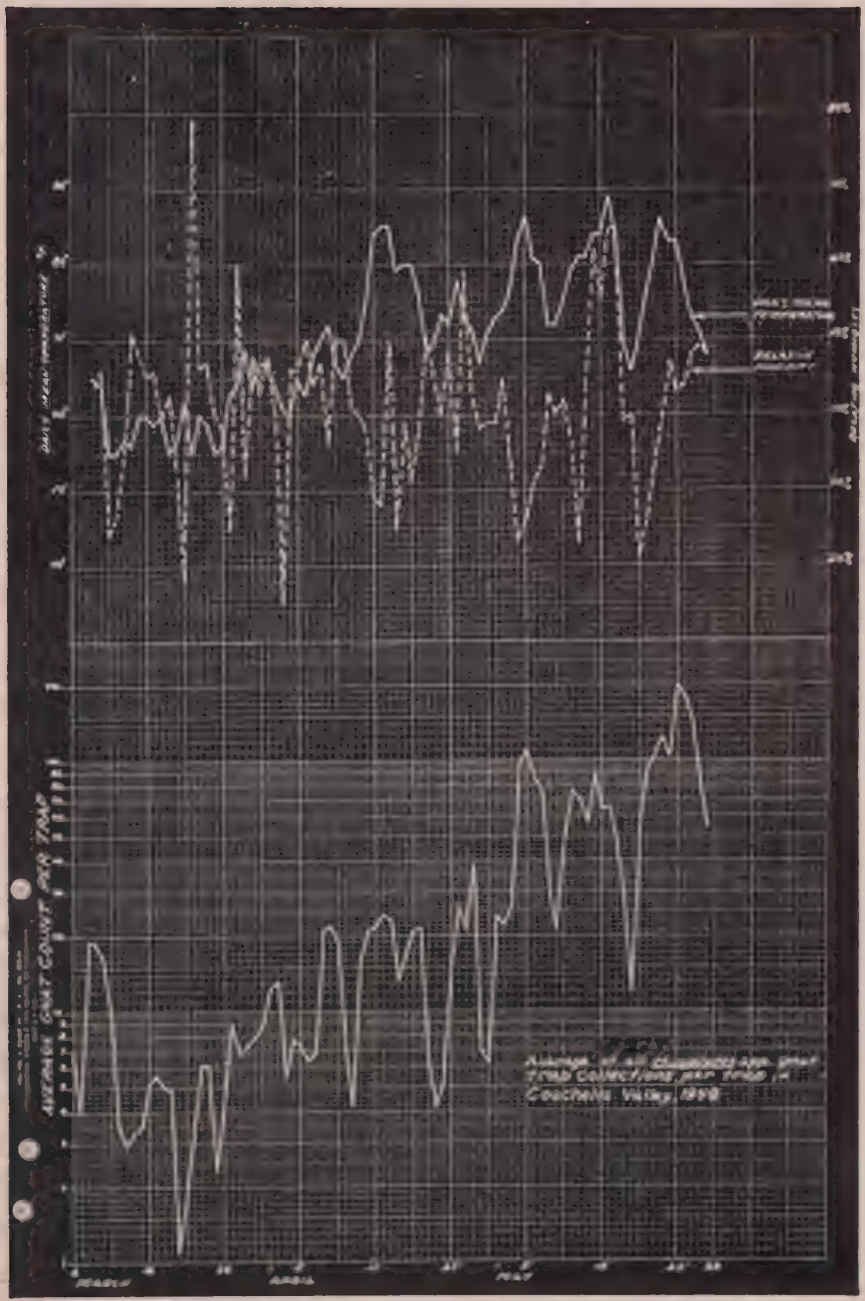

FIGURE 1. Average of all *Hippelates* spp gnat-trap collections per trap in Coachella Valley, 1951

also appears to be one of a series of natural fluctuations.

Pre-treatment Emergence Traps

From 20 pre-treatment emergence traps set out in both treated and untreated plots, a total of 11 gnats was recovered in three traps. Only one trap in each of two untreated plots and one in a dust treated plot captured gnats. Condensed moisture was observed on the interior surfaces of traps, and it is possible that this water-of-condensation may have trapped emerging gnats or the high humidity may have prevented their emergence.

Meteorological and Natural Factors

Among the factors that may have influenced gnat collections were humidity, temperature, season of year, type of vegetation, and cultural practices. Consideration was given to these factors as possible explanations for the results obtained in this study.

The mean daily temperature and relative humidity, as recorded at the U. S. Government Date Garden at Indio, were plotted graphically with average gnat catches for all traps used in this study (Figure 1). The reliability of the gnat counts for the first sixteen days is subject to question as some degree of control was obtained in the ground spray and dusting studies. However, the remainder of the gnat trap counts appears to be reliable as no subsequent control was indicated in these plots. In like manner no control was indicated at any time in the airplane and ground aerosol plots. Study of Figure 1 indicates a clear-cut relationship between temperature and gnat collections, since collections vary directly with mean daily temperature. There does not appear to be a similar correlation with humidity. An over-all seasonal trend following the temperature is seen clearly. As the season advanced the average daily collections increased. This parallels the trend towards higher daily mean temperatures. Again there is no detectable correlation with humidity.

Collections of gnats in citrus groves, date gardens, and grape vineyards closely paralleled each other, increasing and decreasing together. Without considering any seasonal variation, the average number of gnats collected per trap per day for the entire period of the study was determined for each of the three types of habitat. The gnat collections in date palm gardens were largest with an average of 40.6 gnats per trap per day; citrus groves were second with an average of 31.7 gnats per trap per day; grape vineyards yielded the smallest number with an average of 24.1 gnats per trap per day. Early in the season the vineyard collections may have been smaller due to the lack of vegetative growth. Later on when there was a large amount of foliage the collections were more nearly equal to those of the date palm gardens and citrus groves.

Desert Traps

There was considerable speculation as to whether the gnats were limited to cultivated areas in the Coachella Valley. If they were, it was felt that a control program limited to those areas might eventually effect the elimination of these gnats from this valley. On the other hand, if they were found in uncultivated desert areas it would be assumed that a continuous control program would be necessary as cultivated areas would be subject to reinfestation.

With this in mind, three bait traps were operated in an isolated uncultivated desert area. The nearest cultivated areas were the Dos Palmos Ranch, which was three miles away, and the Zimmerer area which was about four miles away. The traps were operated for nine days. Within that time a total of 16 gnats were captured, one trap capturing 10, another—5, and the third—1. The maximum number collected in any one day from a single trap was five. It is possible that the gnats are indigenous to this desert area, and if so, a control program would have to consider the possibility of reinfestation from such sources.

Summary and Conclusions

1. Mosquito control techniques were used in attempts to control *Hippelates* spp. in the Coachella Valley in the spring of 1948. These methods were generally unsuccessful.

2. Two airplane applications of DDT in oil in the form of a thermal aerosol and one application in the form of a water emulsion spray failed to control these gnats. The first aerosol applications were at the rate of 0.1 lb. of DDT per acre and the second one at 0.3 lb. of DDT per acre, while the spray was applied at the rate of 0.4 lb. per acre.

3. Results of ground application of DDT at the rate of one pound per acre, as a spray and as a dust, indicated a small degree of control for at least 27 days and seven days respectively. Ground aerosols applied with a Tifa aerosol generator failed to control the gnats.

4. The pre-treatment emergence traps collected too few gnats to afford any control data. Improved traps are probably necessary before satisfactory collection data can be obtained.

5. Trap collections of gnats varied directly with the daily mean temperature. There was no evident correlation with humidity. As the season advanced the average trap collections increased. This paralleled the seasonal trend toward the higher daily mean temperature.

6. For the whole season more gnats were collected in the date palm gardens than in citrus groves or vineyards. Vineyards produced the fewest gnats early in the season, but later on, the density was nearly equal to that found in the date gardens and citrus groves.

7. Gnats were collected in uncultivated, isolated desert areas in small numbers, suggesting that they are present throughout the valley, and that the desert areas may be a source of reinfestation of cultivated areas.

Acknowledgments

Special acknowledgment is made of the enthusiastic assistance of the residents of the Coachella Valley, the officials of the Coachella Valley Mosquito Abatement District, and the other members of the Bureau of Vector Control, without whose aid this study would have been impossible.

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ASSOCIATION NEWS

ADDRESS BY THE PRESIDENT OF THE ILLINOIS MOSQUITO CONTROL ASSOCIATION, CHICAGO, MARCH 2, 1951

As President of the Illinois Mosquito Control Association it has fallen to my lot to open this session of the American Mosquito Control Association. This is indeed a great honor. We welcome you as our guests and we hope that your stay may be enjoyable as well as instructive.

Activities in mosquito control in Illinois started back in the 1920's. We in the neighborhood of Chicago were infested with the pestiferous mosquito, *Culex pipiens,* largely because of polluted swamp conditions in the Skokie Valley district north of Chicago, and many polluted shallow streams and the old Illinois-Michigan Canal that contributed to ideal conditions for the breeding of mosquitoes as they multiplied toward the fall of the year. Residents in the neighborhood of Highland Park where a music festival was held at night, and people along the valley of the Desplaines River were especially interested in controlling hungry hordes of the floodwater mosquito, *Aedes vexans.* Their efforts led finally to the passage of a bill in the 1927 legislature allowing the formation of districts to be financed by taxes on personal property and real estate.

Four districts in the neighborhood of Chicago, and five others downstate have been formed. It is the four districts in the neighborhood of Chicago that have just joined together into the formation of the Illinois Mosquito Control Association. These districts will be your hosts on the afternoon bus trip.—SPENCER S. FULLER, M.D. (Dr. Fuller died on April 3. See page 109.)

ADDRESS BY THE PRESIDENT OF THE AMERICAN MOSQUITO CONTROL ASSOCIATION, CHICAGO, MARCH 2, 1951

To the membership of the American Mosquito Control Association; Ladies and Gentlemen:

It is customary, at the close of the year, for the retiring President to make a report accounting for his stewardship in directing the affairs of the Association, and relating its accomplishments.

For the past two years the affairs of our Association have been managed by an Interim Board chosen by the membership for the purpose of directing our business until such time as the permanent organization could be established.

The year 1950 was marked by the completion of the By-Laws establishing the Rules and Regulations for the management of the Association, and the submission of these By-Laws to the membership at this Annual Meeting for ratification.

This was a tremendous task, and was complicated by the desire of the Board to anticipate all the problems that might arise and to provide for their solution in a democratic manner. The fact that all communication between members of the Board was conducted by mail made the consideration of the problem time-consuming, and resulted in considerable expense on the part of all concerned. Nevertheless, all did their part and it is the opinion of the Interim Board that the course of our Association will be well charted in the future. To your Interim Board and to Dr. Glasgow must go the thanks of our membership for this job, well done.

The efforts of the Publication Committee and the Editor of MOSQUITO NEWS have resulted in the ever growing reputation of our quarterly journal, MOSQUITO NEWS. This too is the result of personal sacrifice on the part of all those accepting the responsibility and to them must go our appreciation.

During the summer of 1950 a Field Inspection was held for our membership in New England. Under the guidance of our members in Connecticut, Rhode Island, Massachusetts, and Vermont many worthwhile mosquito control accomplishments were inspected and the opportunity was provided for our membership to spend several days together. These inspection trips have proved to be one of the most valuable activities of the Association.

At this time I wish to thank all of the members of our active committees for their unselfish assistance and cooperation during the past year. These committees form the backbone of the Association; without them we would cease to function. My special appreciation goes to Mr. Otto McFeely and his associates for producing this outstanding convention.

In conclusion may I say that our efforts during 1950 have been aimed at the completion of our organization plans without interrupting our usual and customary activities. To me it has been a real pleasure to have had a part in this work, and to your new President will go the privilege of setting our Association on its permanent course toward the accomplishment of its objectives.—LESTER W. SMITH.

NEWS AND NOTES

OF INTEREST TO American Mosquito Control Association members are the activities of the Public Health Insect Control Study and Report Group of the recently organized New England-New York Inter-Agency Committee.

The Group's job is to study and present the existing problems having to do with insects of public health importance in the New England-New York river basins area, to determine the inter-effects of water resources developments on these problems and to recommend basic procedures for their prevention and/or control.

The Group membership includes representatives of the Federal Security Agency (U. S. Public Health Service), Department of Agriculture (Bureau of Entomology and Plant Quarantine), Department of Interior (Fish and Wildlife Service), Department of the Army (Corps of Engineers), and a representative designated by the Governor of each State within the New England-New York area. American Mosquito Control Association members include: Dr. Herbert Knutson, Coordinator of the Group, in the capacity of Special Consultant; Frank R. Lisciotto and John C. Kuschke, who are the Federal Security Agency representatives with headquarters in the Regional Federal Security Agency Office in Boston; Dr. G. H. Bradley, liaison representative with the Communicable Disease Center in Atlanta; and Dr. E. F. Knipling, the U. S. Department of Agriculture representative.

Individual planning conferences have been held in most instances with the State Group representative, who has in turn referred the Coordinator to medical entomologists within the State; however, initial contacts with these medical entomologists, many of whom are American Mosquito Control Association members, have not been completed at the time of this writing (April 30).

HERBERT KNUTSON

DR. SPENCER S. FULLER, author of the Illinois state law authorizing formation of mosquito control districts in Illinois and tax levies for the work, died in his 78th year on April 3, 1951 while working in his garden in Riverside, Illinois. The law was enacted in 1927 and The DesPlaines Valley District was organized at once. Dr. Fuller was elected president and served for 24 years with such success that no complaint was ever made by taxpayers. All flags in Riverside were at half mast on April 6, day of funeral services for Dr. Fuller.

The only other member of the board of trustees of the DesPlaines Valley District who has served since 1927 is Otto McFeely, who was Chairman of Arrangements for the 1951 conference of the American Mosquito Control Association in Chicago. Mr. McFeely was a newspaper writer for 50 years in Indiana and Illinois. He retired in 1941, and since then his only duties have been as a trustee and Treasurer of the District. He was elected by the board to be President pro-tem on April 3.

DR. ENGEL L. R. GILBERT left the University of Maryland on April 1st to take a position with the Production and Marketing Administration, Livestock Branch, Insecticide Division. His work will involve the certification of labels under the Insecticide, Rodenticide, and Fungicide Act of 1947. During the month of January Dr. Gilbert was on active duty as Licutenant, MSC, U. S. Naval Reserve, Jacksonville, Fla.

ERNESTINE THURMAN has just become a commissioned officer in the United States Public Health Service. As a Senior Assistant Sanitarian, Reserve, she will identify mosquitoes which her husband, Deed C., seeks to control in Thailand (Siam). Ernestine with her 4-months old daughter flew from New York the last of May, en route to Bangkok via London, Paris, and Rome.

H. L. T.

DR. AYROZA L. GALVÃO, whose name appeared in a news note on page 153 of the September 1950 issue, has announced the following change of address:

Faculdade de Higiene
Caixa Postal 8099 (formerly 99-B)
São Paulo, Brazil

Dr. Galvão is associated with the Department of Parasitology at the University of São Paulo.

H. L. T.

DR. LLEWELYN F. GUNARATNA, Medical Officer, Antimalaria Campaigns, in Ceylon, was a visitor to the United States in May. During the first part of that month, he inspected the laboratories of the U. S. Department of Agriculture at Beltsville, Md., and those of the National Institutes of Health at Bethesda, Md. Dr. Gunaratna was en route from England to the southern states and South America. He will visit Cyprus, Sardinia, Greece, and India before he returns home five months hence, where his permanent address is Torrington Square, Colombo, Ceylon.

H. L. T.

IN A PRIVATE CEREMONY, Dr. Roberto Levi-Castillo was decorated a Commendator of the Military Order of San Georgio de Antioquia by the Vatican State. The decoration included the Star of Merit and was awarded to Dr. Castillo because of his studies having to do with the control of disease-carrying mosquitoes in the Catholic Missions in Ecuador. Dr. Castillo is now lecturing in the University of Cuenca on "Diseases Transmitted by Mosquitoes and Their Control."

H. H. STAGE

NEW OFFICERS ELECTED IN STATE ASSOCIATION: The new officers of the California Mosquito Control Association (elected at Riverside, March 13, 1951) are:

President—Edgar A. Smith, Merced
Vice-President—Rolland L. Henderson, Tulare
Secretary-Treasurer—Arthur F. Geib, Bakersfield
Directors—Adolph E. Preuss, Selma; Jack H. Kimball, Santa Ana; G. Paul Jones, San Rafael; Joseph D. Willis, Redding; Edward D. Davis, Fresno; Norman Ehmann, Los Angeles.

AT THE SPRING MEETING of the New Jersey Mosquito Extermination Association, the following officers were elected:

President—Maximilian M. Stallman, East Orange
First Vice-President—Floyd P. Ayres
Second Vice-President—Charles T. Foulk, 2nd
Secretary—Dr. Bailey B. Pepper
Treasurer—Lester W. Smith.

AT THE TWENTY-SECOND ANNUAL MEETING of the Florida Anti-Mosquito Association held at Key West, April 29th to May 2nd, 1951, the following officers were elected:

President—LCdr. John M. Hirst, Jacksonville
President-elect—V. Samuel Minnich, Daytona Beach
First Vice-President—J. Melton Williams, Sarasota
Second Vice-President, Dr. Maurice W. Provost, Orlando
Secretary-Treasurer—John A. Mulrennan, Jacksonville.

THE FOLLOWING OFFICERS of the Utah Mosquito Abatement Association were elected at the annual meeting, March 19 and 20, 1951:

President—Dr. O. Whitney Young, Weber County Mosquito Abatement District
Vice-President—Harry Drew, Box Elder Mosquito and Fly Abatement District
Secretary-Treasurer—Robert A. Wilkins, Salt Lake City Mosquito Abatement District.

W.H.O. EXPERT COMMITTEE ON INSECTICIDES

Word has been received that the next meeting of the W.H.O. Expert Committee on Insecticides will be July 30–August 4, at the Communicable Disease Center Laboratory in Savannah, Georgia. A.M.C.A. members on the committee are: T. H. G. Aitken, J. M. Andrews, G. H. Bradley, A. D. Hess, C. W. Kearns, F. W. Knipe, K. D. Quarterman and H. H. Stage. The provisional agenda includes a discussion on the establishment of specifications for sprayers, dusters, and mechanically operated compressors for compression sprayers.

REVIEWS AND ABSTRACTS

TREATMENT OF MOSQUITO LARVAE AND ADULTS WITH RADIOACTIVE PHOSPHORUS. By W. W. Yates, C. M. Gjullin, and A. W. Lindquist. Jour. Econ. Ent., 44(1):34–37, Feb., 1951. Studies were made to determine how to introduce radioactive phosphoric acid (P^{32}) into both larvae and adult mosquitoes in amounts that would be detectable with radioactive measuring devices. *Aedes sticticus* (Meig.) and *A. vexans* (Meig.) mosquitoes gave 544 to 897 cpm. above background after they had been allowed to feed on the blood of rats that had received 0.375 millicurie of P^{32} in aqueous solution intraperitoneally 24 hours earlier. In three dissected specimens an average of 72 per cent of the radioactivity was found in the abdomen and 4 per cent in the legs.

Second- and third-instar larvae of *Culex tarsalis* (Coq.) reared in water having an unknown concentration of P^{32} had radioactivity ranging from 164 to 417 cpm. Fifteen per cent of this radioactivity was present in the legs and 45 per cent in the abdomen.

Aedes sticticus females fed on water having an unknown concentration of P^{32} gave readings of 577 to 1,192 cpm. one to 13 days later. The legs had approximately 9 per cent and the abdomens 41 per cent of the total radioactivity.

Aedes sticticus and *A. vexans* adults reared from the second-stage larvae in water containing 0.05 μc of P^{32} per milliliter gave average readings of 41,147 cpm. for females and 39,072 for males. In later tests dosages of 0.01, 0.001, and 0.0001 μc per milliliter gave 14,911, 1,612, and 522 cpm. respectively for the females.

It is suggested that a concentration of approximately 0.0001 μc of radioactive phosphoric acid per milliliter may be a practical dosage for the treatment of larvae in flight studies of adults. Since adults may be readily tagged by feeding them sugar solutions containing small amounts of P^{32}, the use of this method may be desirable in many studies.—Authors' summary.

DDT-RESISTANT HOUSE FLIES AND MOSQUITOES. King, W. V. Jour. Econ. Ent. 43:527–532, Aug., 1950. This article reports briefly on the work conducted by the Orlando laboratory during 1949. Chlordane emulsions showed promise as residual treatments against DDT-resistant house flies. Flies from different sources showed varying degrees of susceptibility to DDT in consecutive generations. Evidence was obtained that salt-marsh mosquitoes, *Aedes sollicitans* and *A. taeniorhynchus* from previously intensively treated areas are continuing to develop resistance to DDT and TDE, but they were susceptible to lindane, chlordane, parathion and dieldrin in laboratory tests. In laboratory tests with adults of *A. pseudopunctipennis* from a Mexican village where all premises had been treated with DDT residual sprays once each year during the previous three years, there was no indication of increased resistance to this material.—Wm. E. Bickley, University of Maryland, College Pk., Md.

AERIAL SPRAY TESTS ON ADULT SALT-MARSH MOSQUITOES RESISTANT TO DDT. Deonier, C. C., Cain, T. L. Jr., and McDuffie, W. C. Jour. Econ. Ent. 43:506–510, Aug., 1950. Field observations and laboratory tests gave evidence that *Aedes taeniorhynchus* and *A. sollicitans* in the Cocoa Beach area of Brevard County, Florida, were resistant to DDT in 1949. Several series of tests were carried out to evaluate the effectiveness of lindane, technical benzene hexachloride (12 per cent gamma isomer), toxaphene, parathion, chlordane and dieldrin as well as DDT. Lindane at 0.1 pound per acre is reported as being the most effective. Technical benzene hexachloride, dieldrin, and parathion compared favorably with lindane in certain concentrations, under certain conditions.—W. E. B.

BARRIER STRIP AND PRE-FLOOD TREATMENTS WITH DDT TO CONTROL *Anopheles quadrimaculatus*. Ludvick, F. F. Jour. Econ. Ent. 43:516–517, Aug., 1950. A barrier strip was treated by means of ground equipment with a residual spray at a rate of approximately 280 mg. DDT per square foot or about 136.5 pounds of DDT per acre. The barrier strip was 50 feet wide and 10 feet high, and dense marginal vegetation bordered most of the breeding area of about 22 acres. Rhodamine B was used to dye 5,000 insectary reared *A. quadrimaculatus* which were released within the barrier. During the eight weeks after treatment 0.12 per cent were recovered. The results suggest that the barrier was highly effective in controlling *A. quadrimaculatus*.

A pre-flood application of DDT by airplane at the rate of 1.4 pounds per acre to about 125 acres of marsh appeared to retard larval development for about seven weeks and to delay the build-up of the adult population.—W. E. B.

ECOLOGICAL SURVEY OF THE MOSQUITOES OF GREAT WHALE RIVER, QUEBEC. Jenkins, D. W. and Knight, K. L. Proc. Ent. Soc. Wash. 52:209–223, Oct., 1950. The area surveyed is on the eastern shore of Hudson Bay and is in the Transition Zone between the arctic tundra and the northern transcontinental conifer forest. The principal habitats of mosquito larvae are modified rock pools, bog and tundra pools, and small oxbow lakes. Fifteen species of culicids including four chaoborines were observed and biological data on each of them are given. The most important pest species were *Aedes communis, A. pullatus,* and *A. excrucians*.—W. E. B.

FACTORS INFLUENCING SPRAY AND THERMAL AEROSOL APPLICATION BY AIRPLANE. Cutkomp, L. K., Hess, A. D., and Keener, G. G. Jour. Econ. Ent. 43:456–462, Aug., 1950. The T.V.A. is continuing extensive studies on the most practical and effective methods of applying DDT and other insecticides for the control of *Anopheles quadrimaculatus* larvae, and this report supplies new information as to the conditions under which thermol aerosols and sprays can best be used. A Consolidated Vultee BT-13 was equipped with both a thermol aerosol unit and a five-nozzle spraying system. Factors compared and discussed are: type of breeding place; degree of atomization; size, number and deposition of particles; swath width; density of spray; application height; and temperature. Ordinarily the aerosol could not be effectively used above 35 feet. The spray is often advantageous because it can be applied from a height greater than 50 feet.—W. E. B.

SOME HABITATS OF EGGS OF *Aedes vexans*. Bodman, M. T. and Gannon, N. Jour. Econ. Ent. 43:547–548, Aug., 1950. Soil samples from ten stations subject to inundation in Champaign County, Ill. were removed to the laboratory, and the number of viable eggs determined on the basis of the number of hatched larvae. Eggs were present in debris on the surface and down to a depth of 2 inches. Heavier soils are more suitable for oviposition than lighter soils. Eggs were found only in spots which have some form of shade. Where the margin of transient pools is steep, the band around it where eggs are deposited is narrow. All of these situations influence retention of moisture.—W. E. B.

FOUR NEW MOSQUITO RECORDS FROM UTAH (Diptera: Culicidae). Don M. Rees and Lewis T. Nielsen. Pan-Pacific Entomologist, 27(1):11–12, 1951. Additional species of mosquitoes listed as occurring in Utah are: *Aedes impiger* (Walker)—fairly common in northern Utah at elevations ranging from 6,000 to 9,000 feet; *Aedes nearcticus* Dyar—found in an alpine meadow at an elevation of 10,100 feet in the Uintah Mountains, Summitt County; *Culex apicalis* Adams—a single larva taken at Kamas, Summitt County, at an elevation of 6,400 feet; and *Culex quinquefasciatus* Say—males recorded from northern and southern areas of Utah in lower valleys at elevations below 5,000 feet.—Ernestine B. Thurman, National Institutes of Health, Bethesda, Md.

HALLAZGO DE *Anopheles aztecus* HOFFMANN NATURALMENTE INFECTADO CON PLASMODIUM EN LA ZONA DE XOCHIMILCO, D. F. (The finding of *Anopheles aztecus* Hoffmann naturally infected with Plasmodium in the zone of Xochimilco, D. F.) By W. G. Downs and E. Bordas. Revista del Instituto de Salubridad y Enfermedades Tropicales 10(4):3–7. Mexico, D. F., Dec., 1949. In dissections of *A. aztecus* Hoffmann from house captures in the Xochimilco-Mixquic region of the Valley of Mexico, one specimen was encountered with an oocyst infection of the gut and one specimen with an oocyst infection of the gut and sporozoites in the salivary glands. This finding, coupled with epidemiological observations, serves to implicate *A. aztecus* as the vector of malaria in the region.—Authors' summary.

TRANSMISSION OF *Plasmodium relictum* GRASSI & FELETTI BY *Anopheles freeborni* AITKEN. Frances F. Mok. Science 113(2939):485, April, 1951. This is the first report of the successful transmission of *Plasmodium relictum* from canary to canary by *Anopheles freeborni*. *Culex pipiens molestus* (most frequently referred to as the autogenous form of *pipiens* or as *C. pipiens autogenicus*) was used as the control species. The results of the described experiments furnish additional evidence that avian plasmodia can be transmitted by anopheline mosquitoes.—D. V. Jensen, National Institutes of Health, Bethesda, Md.

SOME NUTRITIONAL REQUIREMENTS OF ADULT MOSQUITOES *(Aedes aegypti)* FOR OVIPOSITION. Joseph Greenberg. Jour. Nutrition 43(1):27–35, Jan., 1951. By employing a previously described method for artificially feeding adult mosquitoes through a membrane (MOSQUITO NEWS 9(2):48–50, 1949), the nutritional requirements for oviposition by adult *Aedes aegypti* were studied. These mosquitoes laid 16 times as many eggs per female when fed defribinated sheep blood as when fed washed sheep erythrocytes. A series of inorganic salts, vitamins, and glucose, when added to sheep erythrocytes, failed to increase oviposition significantly. Oviposition was markedly increased by feeding such proteins as bovine plasma albumin, human plasma albumin, egg albumin, human gamma globulin, gelatin and casein, and a tryptic digest of casein. The proteins could be replaced almost completely by DL-isoleucine, but not by a combination of the other 9 amino acids which are essential for rats. However, even when sheep erythrocytes were supplemented with the optimum concentrations of proteins or DL-isoleucine, oviposition did not equal that achieved with defibrinated sheep blood. An extension of studies of this type could lead to the discovery of fundamental information not only in mosquito physiology but in the physiology of other insects and of higher animals as well.—E. S. Josephson, Biochemist, National Institutes of Health, Bethesda, Md.

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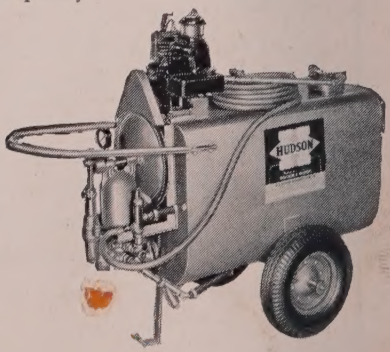

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